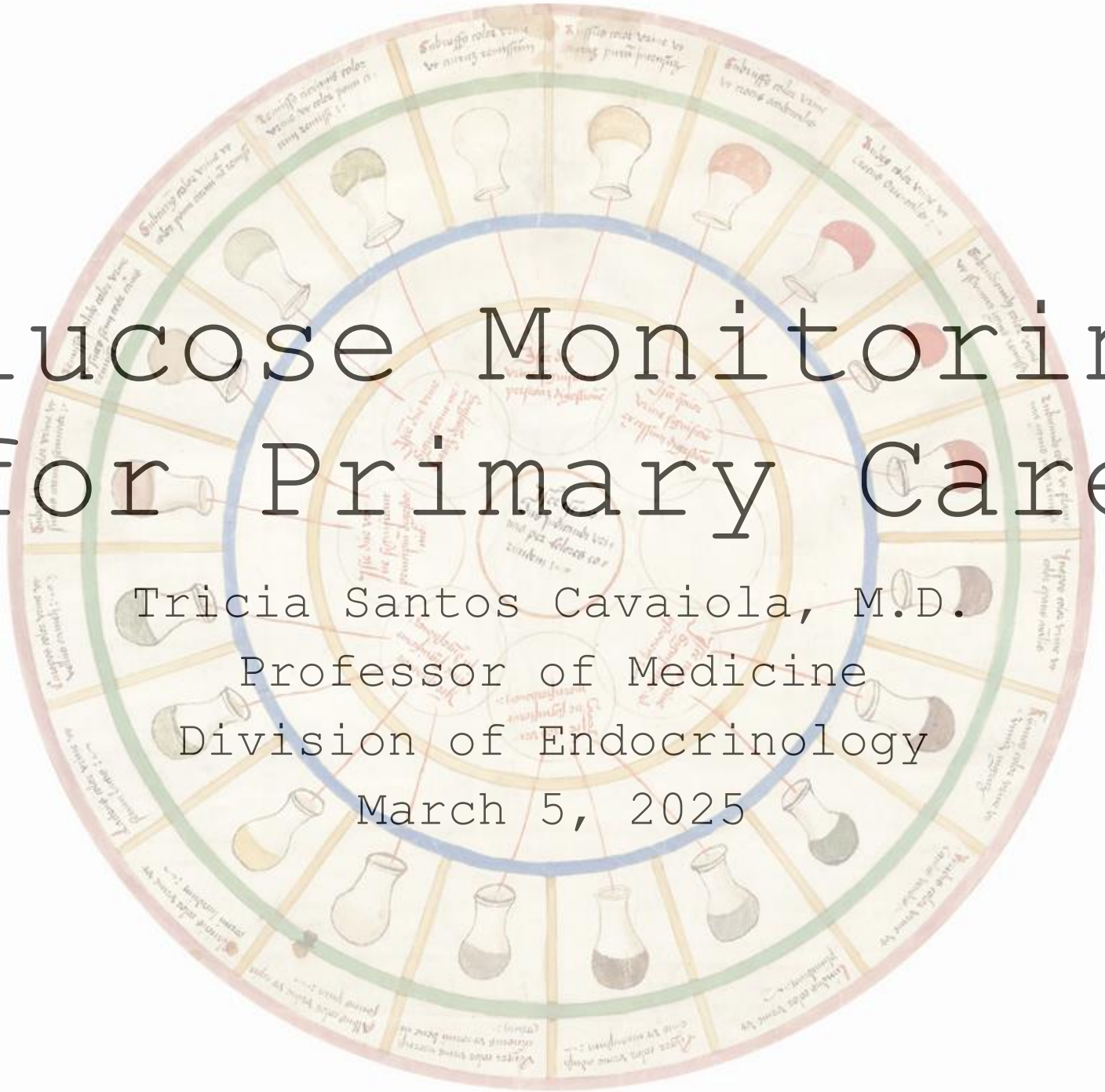


Glucose Monitoring for Primary Care

Tricia Santos Cavaiola, M.D.
Professor of Medicine
Division of Endocrinology

March 5, 2025

A1c

1950's 1980's 2000's

Glucose monitoring timeline

Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - Accuracy & discrepancy with home glucometers
  - Available brands on the market & how to prescribe them
  - Clinical Utility
  - How to analyze the data
- Overview of over-the-counter CGM

Glucose Monitoring for Primary Care

- **Utility and limitations of A1c and glucometer use**
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - Accuracy & discrepancy with home glucometers
  - Available brands on the market & how to prescribe them
  - Clinical Utility
  - How to analyze the data
- Overview of over-the-counter CGM

Why Hemoglobin A1c?

The New England
Journal of Medicine

Volume 329 SEPTEMBER 30, 1993 Number 14

THE EFFECT OF INTENSIVE TREATMENT OF DIABETES ON THE DEVELOPMENT AND PROGRESSION OF LONG-TERM COMPLICATIONS IN INSULIN-DEPENDENT DIABETES MELLITUS

THE DIABETES CONTROL AND COMPLICATIONS TRIAL RESEARCH GROUP*

Diabetes Care Volume 37, January 2014 9

The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Study at 30 Years: Overview

*David M. Nathan, for the DCCT/EDIC Research Group**

THE LANCET

Log in R

ARTICLES | VOLUME 352, ISSUE 9131, P837-853, SEPTEMBER 12, 1998

Purchase Su

Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33)

UK Prospective Diabetes Study (UKPDS) Group*

Published: September 12, 1998 • DOI: https://doi.org/10.1016/S0140-6736(98)07019-6

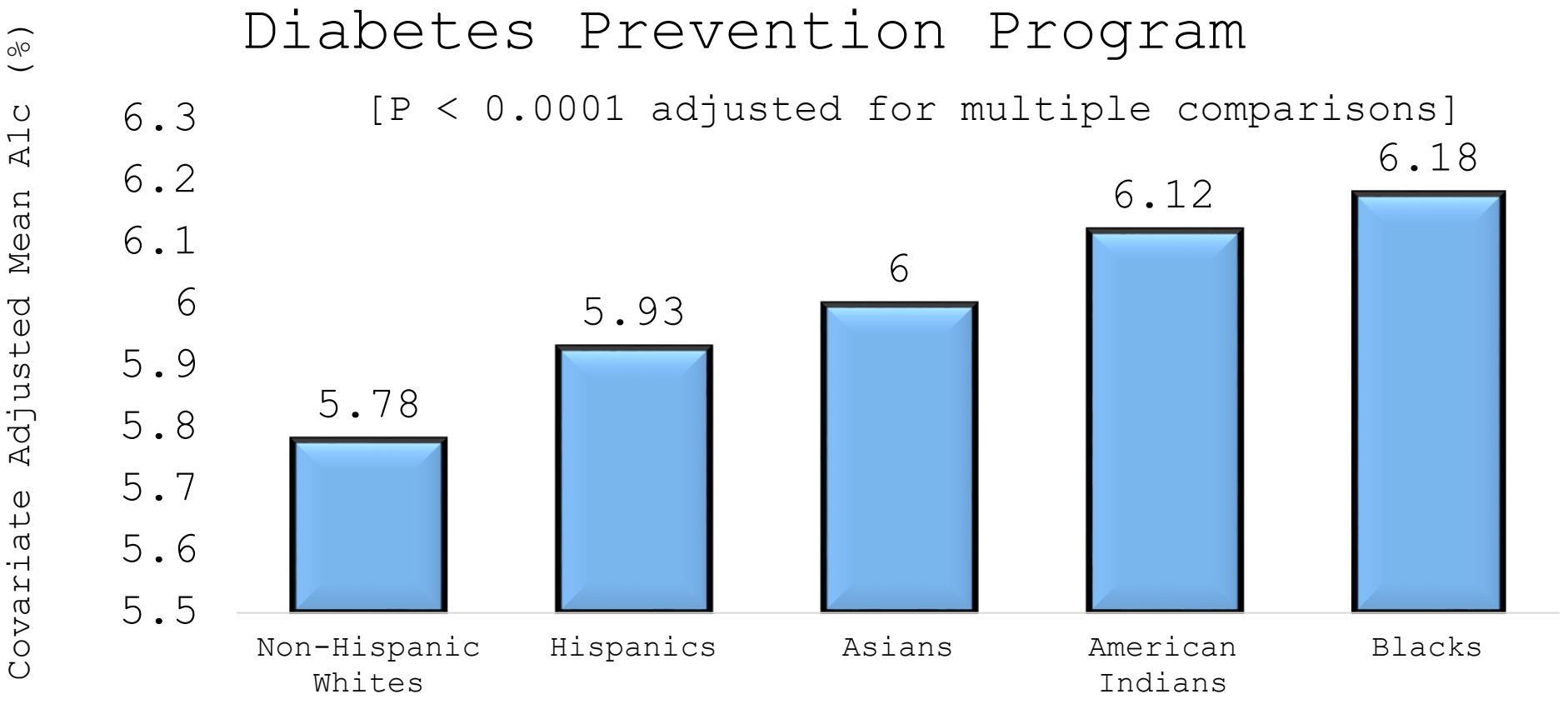
THE LANCET
Volume 352, Issue 9131, 12 September 1998, Pages 854-865

Articles

Effect of intensive blood-glucose control with metformin on complications in overweight patients with type 2 diabetes (UKPDS 34)

UK Prospective Diabetes Study (UKPDS) Group

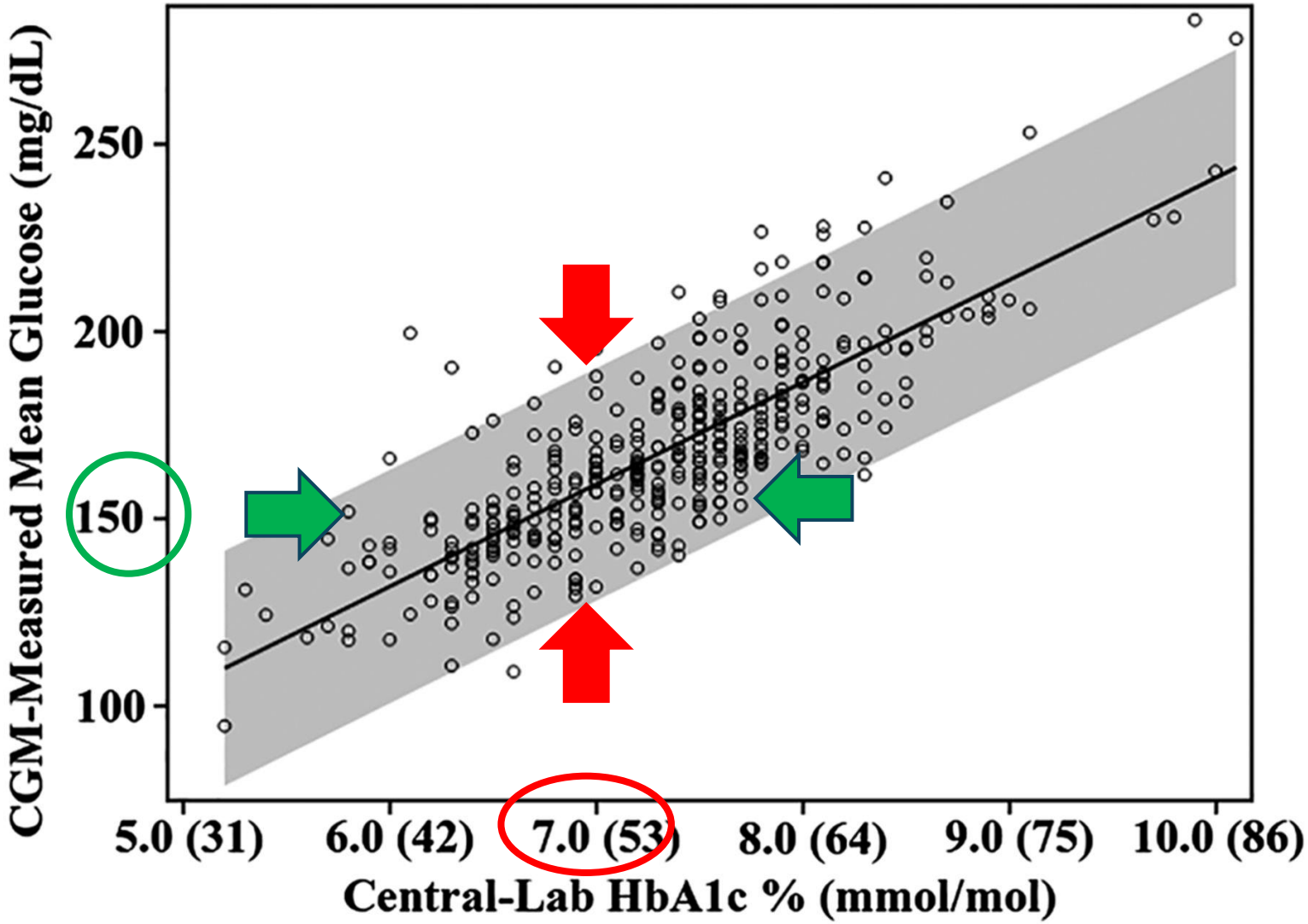
A1c levels are variable for different racial and ethnic groups



* Adjusted for age, gender, marital status, education, BMI, hematocri

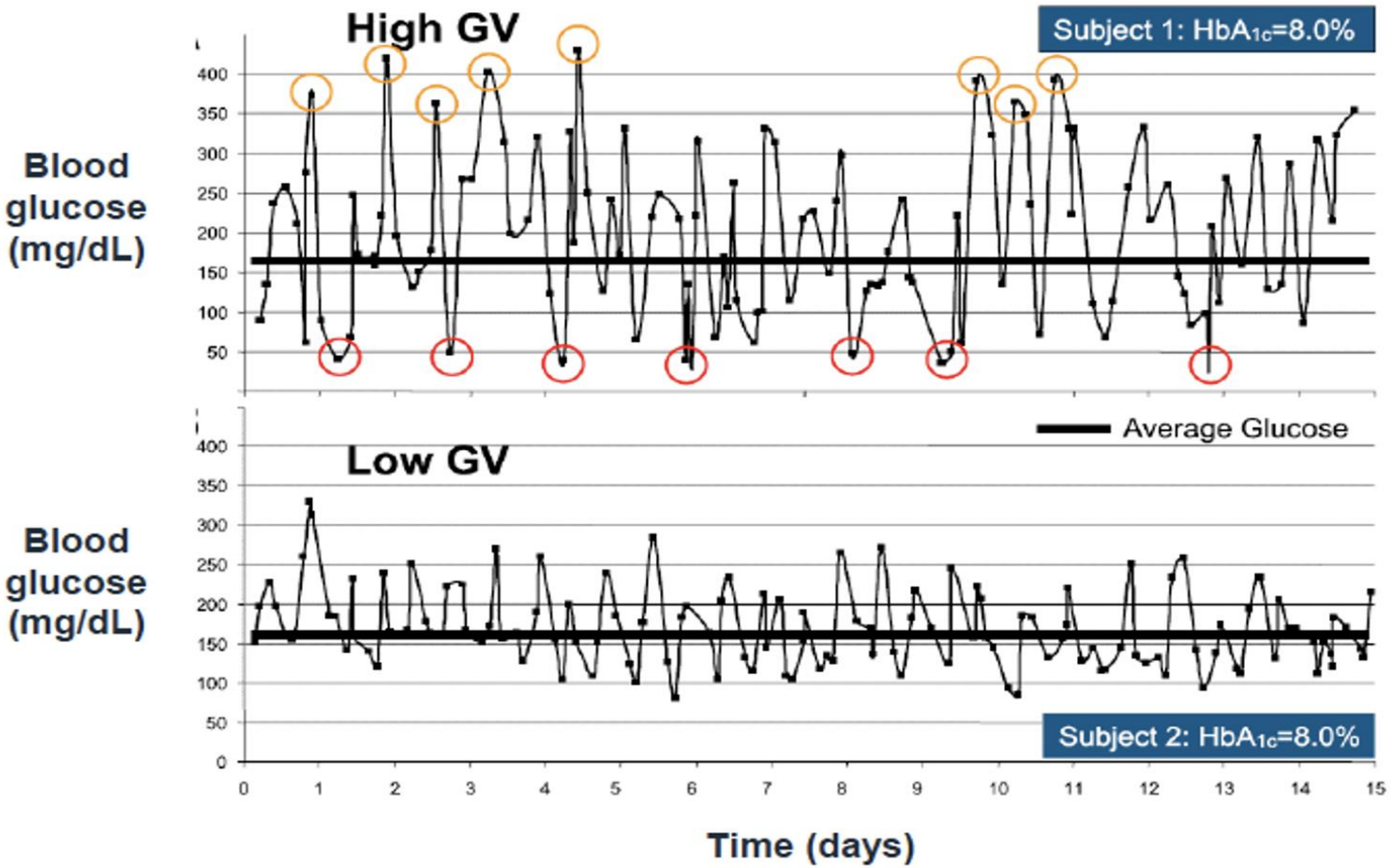
Herman WH, et al. Diabetes Care 2007.

"The Fallacy of Average: How Using HbA_{1c} Alone to Assess Glycemic Control Can Be Misleading"



Beck RW et al. Diabetes Care 2017.

Average glucose estimated from A1c does not detect daily glucose fluctuations or trends



Two patients with Type 1 DM, Same A1c

1. Kovatchev B et all. Diabetes Care. 2016 2. Suh S et al. Diabetes Metab J. 2015 3. Bergenstal RM. Diabetes Care. 2015. 4. Beck RW et al. Diabetes Care. 2019

Slide courtesy Dr. Steve Edelman

Conditions that can cause discordance between A1c and home glucose monitoring

Falsely low

- Glucose-6-phosphate dehydrogenase deficiency
- Hemoglobin variants (sickle cell)
- Blood transfusion
- Hemolytic anemia
- Pregnancy
- HIV tx (NRTIs)
- Blood donation
- Erythropoietin

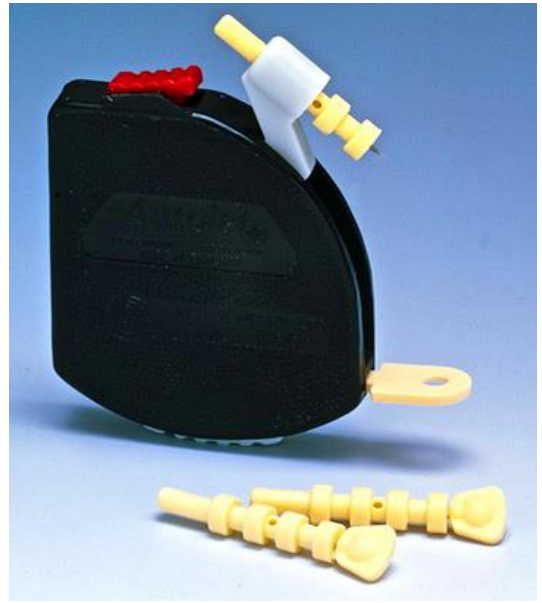
Falsely elevated

- Iron, B12, folate deficiencies
- Elevated urea (ESRD)
- Hemoglobin variants

[1] Kim PS, et al. Diabetes Care 2009.
ADA Standards of Medical Care in Diabetes. Diabetes Care Jan 2020

Self Monitoring Blood Glucose (SMBG) with glucometer

- May be helpful in insulin-treated
- Data less clear for non-insulin users
- Single point of time measurement
- May be difficult to interpret data
- Dependent on patient decision to monitor
  - Avoidance
  - Pointlessness
  - Burden



Danne, et al. Diabetes Care 2017. International Concensus statement on CGM.

Glucometer Accuracy

Outpatient Meter Standards

- 95% of values must be within 15% of the true value
- 99% of values must be within 20% of the true value

Inpatient POC Standards

- 95% of values should be within 12% of the reference value for blood sugars over 75 mg/dl, and within 12 mg/dl for blood sugars below 75 mg/dl
- 98% of values should be within 15% of the reference value for blood sugars over 75 mg/dl, and within 15 mg/dl for blood sugars below 75 mg/dl

https://www.fda.gov/regulatory-information/search-fda-guidance-documents/self-monitoring-blood-glucose-test-systems

Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - **How they work**
  - Accuracy & discrepancy with home glucometers
  - Available brands on the market & how to prescribe them
  - Clinical Utility
  - How to analyze the data
- Overview of over-the-counter CGM

CGMs are wearable sensors that measure interstitial glucose

Traditional CGM systems have 3 parts

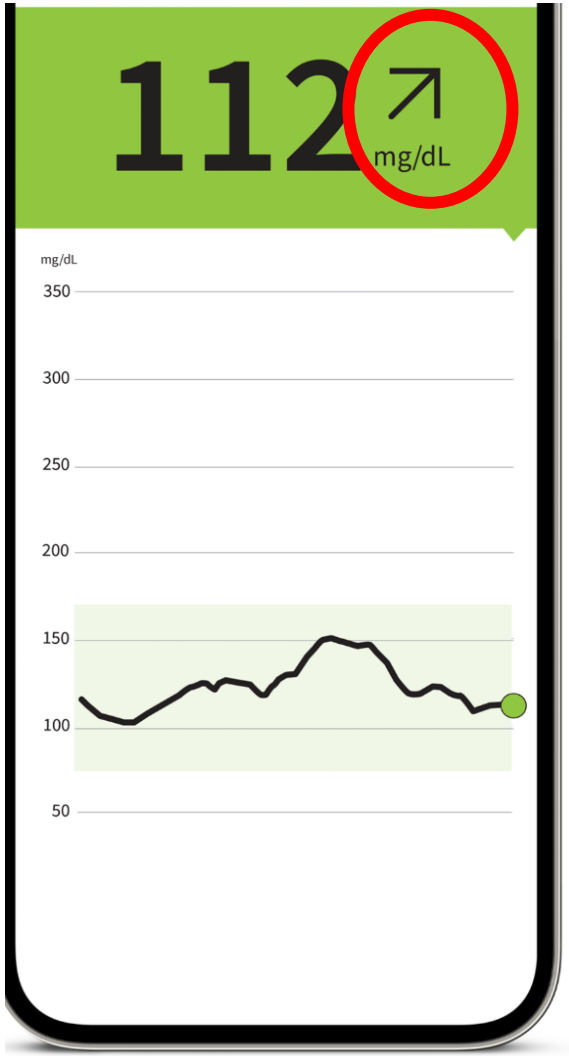
1. Subcutaneous glucose sensor
    - Measures glucose in the interstitial fluid
2. Transmitter
    - Sends glucose measurements to receiver via bluetooth
3. Receiver/smartphone/smartwatch

Data display and features

- Customizable alerts and alarms
- Fixed urgent low
  /dL

Glucose

Trend arrow



Target range

Recent glucose trend

*Share/follow

Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - **Accuracy & discrepancy with home glucometers**
  - Available brands on the market & how to prescribe them
  - Clinical Utility
  - How to analyze the data
- Overview of over-the-counter CGM

Mean Absolute Relative Difference (MARD)

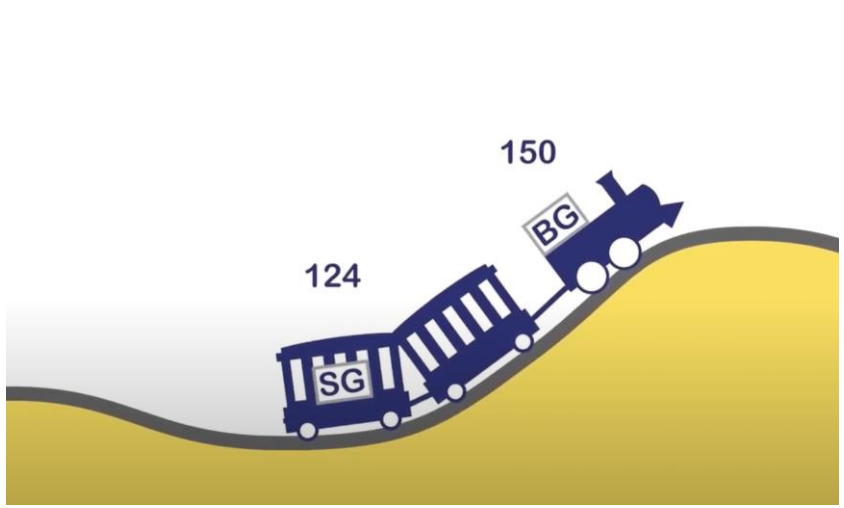
- Average of the absolute error between all CGM values and matched reference values
- Small percentage indicates that the CGM readings are close to the reference glucose value

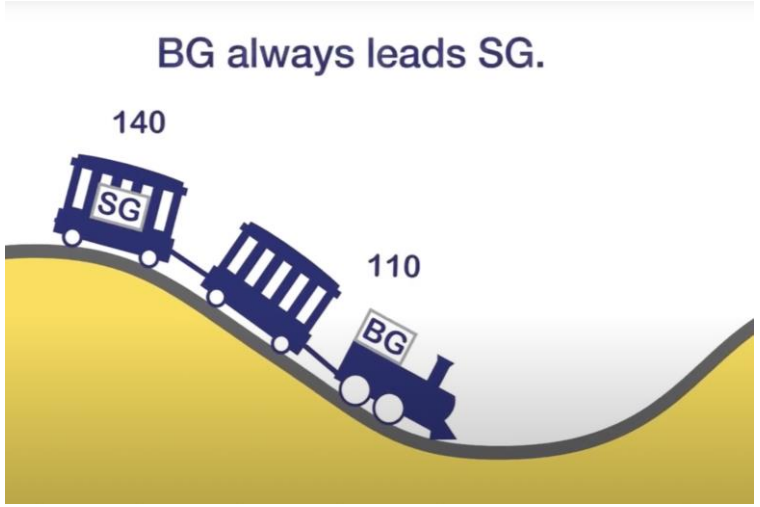
CGM	MARD
Dexcom G7	8.2%
Freestyle Libre 3 plus	8.2%
Medtronic Simplera	10.2%
Senseonics Eversense	8.5%

Kruger, et al. CGM in Clinical Practice 2018.
Danne, et al. Diabetes Care 2017. International Consensus statement on CGM.

Discordance between CGM and glucometer

- Gold standard is serum glucose
- Expect ~ 30mg/dL difference, ~ 50 mg/dL is acceptable
- Discordance is more prominent when glucose is changing rapidly





https://www.diabetescare.abbott

BG = blood glucose; SG = sensor/CGM glucose

Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - Accuracy & discrepancy with home glucometers
  - **Available brands on the market & how to prescribe them**
  - Clinical Utility
  - How to analyze the data
- Overview of over-the-counter CGM

Available CGM Systems

Dexcom G7

Freestyle Libre 3 Plus

Medtronic Simplera

Sensionics Eversense 365

Presented in alphabetical order

Dexcom G7®

- Wear time: 10 days
- Data transfer: every 5 minute
- Warm up: 30 minutes
- Alerts and alarms: customizab
  - Delay first high
  - Predictive urgent low soon
- Connects directly to Apple wa

Dexcom G7 Application

https://www.youtube.com/watch?v=YU8tib41-_4

Freestyle Libre 3 Pl

- Wear time: 15 days
- Data transfer: every minute
- Warm up: 60 minutes
- Alerts and alarms
- Smallest/thinnest

Freestyle Libre 2
- Size 2 stacked quarters
- Reads glucose with scan
- Must scan every 8 hours to get historical data

Freestyle Libre 3
- Size 2 stacked pennies
- Glucose values automatically pushed to reader

New Rx for 3 or 2 *plus* in 8/2025. Can use same app/reader

Freestyle Libre 3 plus application

https://www.youtube.com/watch?v=ePnLXUcdBfc

Medtronic Simplera

- Wear time: 7 days
- Data transfer: every 5 minutes
- Warm up: 2 hours
- Alarms and alerts
- Upgrades from recent Guardian
  - No calibration
  - All in one transmitter/sensor
  - Disposable
  - No charging

Medtronic Simplera application

https://m.youtube.com/watch?v=0Vs6th5NBbQ

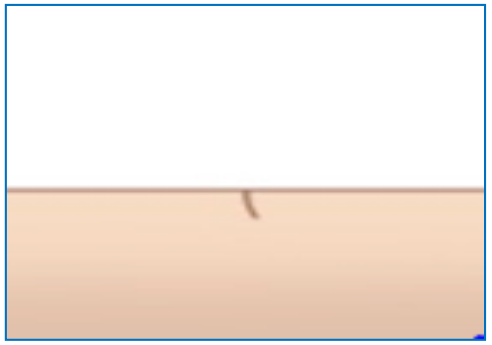
Senseonics Eversense 365®

- Implantable
- Wear time: 12 months
- Data transfer: every minute
- Warm up: 24 hours
- Calibration: once a week after first 2 weeks
- External transmitter - removable
- Customizable & predictive alerts, vibration on body
- Silicone based adhesi

Christiansen MP, et al. Diabetes Tech Therap. 2017

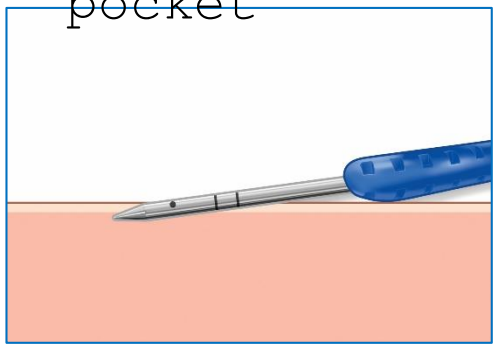
Eversense 365 Sensor Insertion

1. Make incision



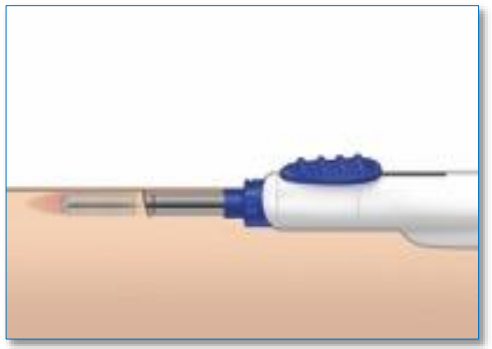
5-8 mm Incision Upper Arm (lidocaine)

2. Create subcutaneous pocket



Approximately 3-5 mm below skin surface

3. Insert sensor



Sensor Inserted with Custom Inserter

4. Close wound

Steri-Strips™ to Close

Prescribing CGM

- Rx for sensors (# per month)
  - Freestyle libre 3 # 2 per month (15 day wear)
  - Dexcom G7 # 3 per month (10 day wear)
  - Medtronic Simplera #4 per month (7 day wear)
- Rx for reader (# 1 per month) *or* compatible smartphone

❖Commercial insurance: most will let you order directly to pharmacy

❖Medicare: some require placing order through DME

Requirements: Insulin treated or non-insulin treated with problematic hypoglycemia

❖Eversense 365: refer to endocrinology

Out of pocket cost/month varies by pharmacy

- FreeStyle Libre 2 and 3 - about $140 to $150 per month
- Dexcom G6 and G7 - about $170 to $180 per month
- Medtronic Guardian 4 - about $280 for a five-week supply
- Eversense E3 - about $1,500 to $1,600 per year

https://diatribe.org/diabetes-technology/how-navigate-cgm-insurance-

Billing and Coding

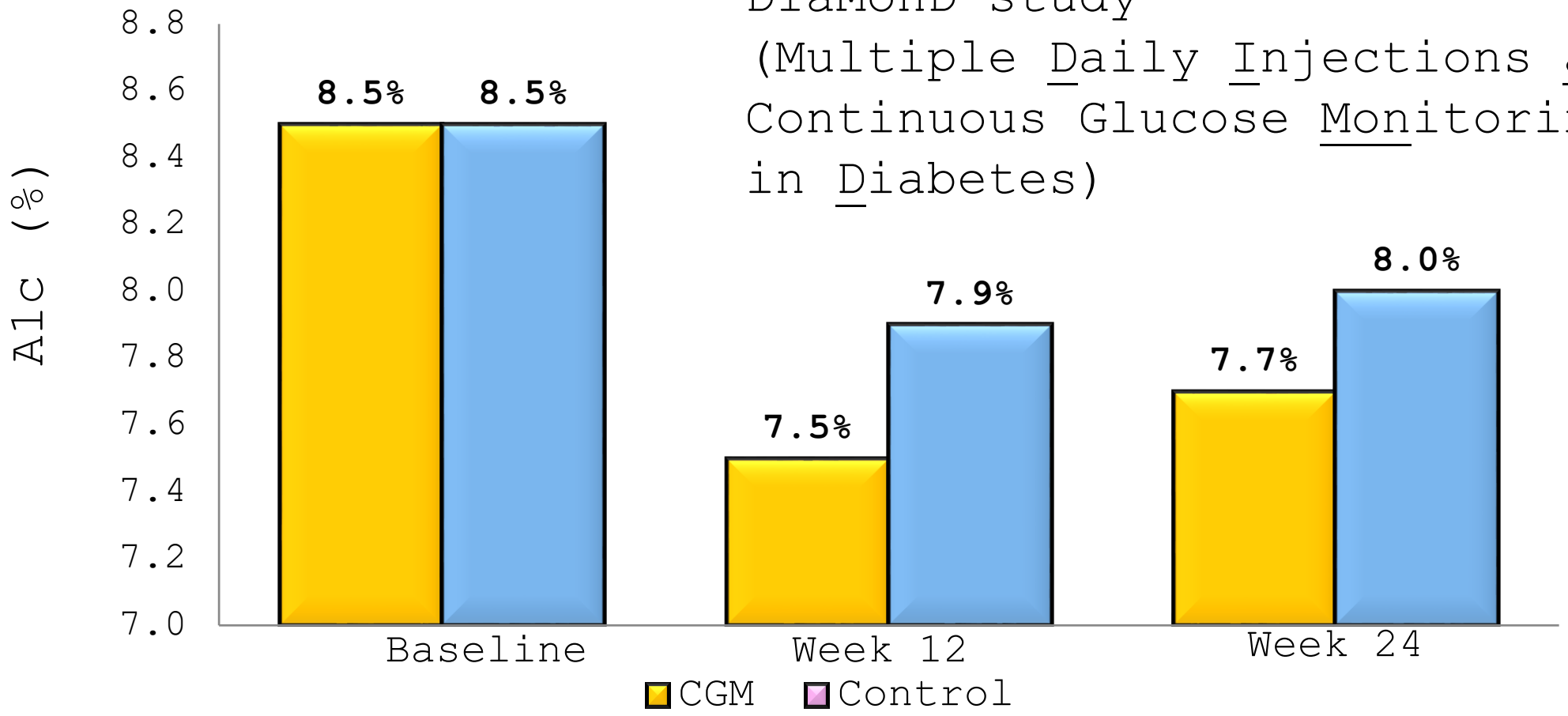
Dexcom CPT Codes and CPT Code Description	Medicare physician office fee schedule[1]	Medicare outpatient diabetes center[2]	Private payer (2024 averages)[3]	Relative value unit (RVU) non-facility[1]
CGM Services				
CPT 95249 Personal CGM - Startup/Training Ambulatory continuous glucose monitoring of interstitial tissue fluid via a subcutaneous sensor for a minimum of 72 hours; patient-provided equipment, sensor placement, hook-up, calibration of monitor, patient training, and printout of recording. *Bill only once during the time period that the patient owns the device.**	$65.24	$58.28 APC 5733	$130	1.96
CPT 95251 CGM Interpretation Ambulatory continuous glucose monitoring of interstitial tissue fluid via a subcutaneous sensor for a minimum of 72 hours; analysis, interpretation and report. *Do not bill more than 1x/month.**	$34.29	Paid under physician fee schedule	$98	1.03

Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - Accuracy & discrepancy with home glucometers
  - Available brands on the market & how to prescribe them
  - **Clinical Utility**
  - How to analyze the data
- Overview of over-the-counter CGM

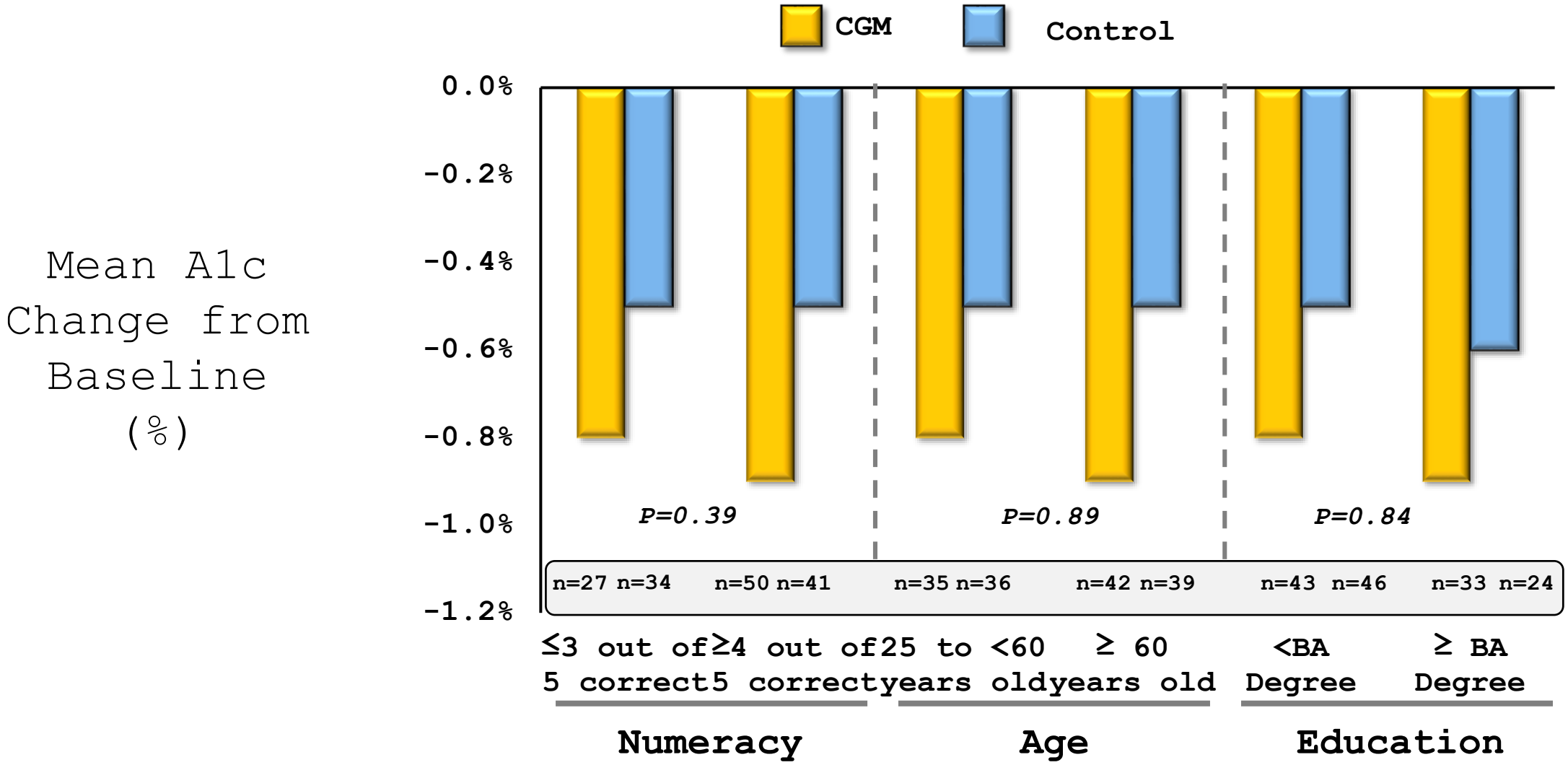
CGM as a therapeutic intervention in Type 2 Diabetes on Insulin

DIaMonD study
(Multiple Daily Injections and Continuous Glucose Monitoring in Diabetes)



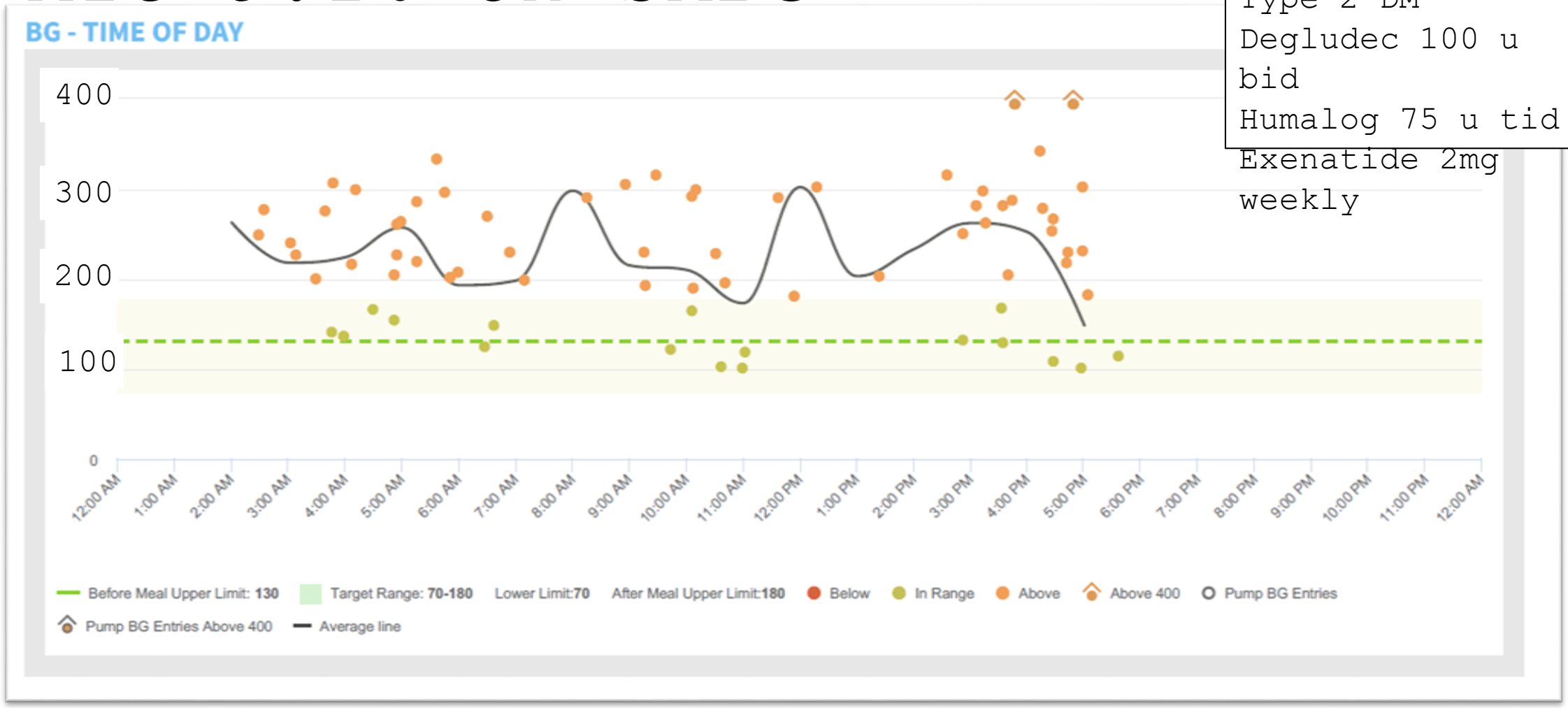
Beck RW, et al. Annals of Internal Medicine. 2017

No difference in outcomes in various subgroups



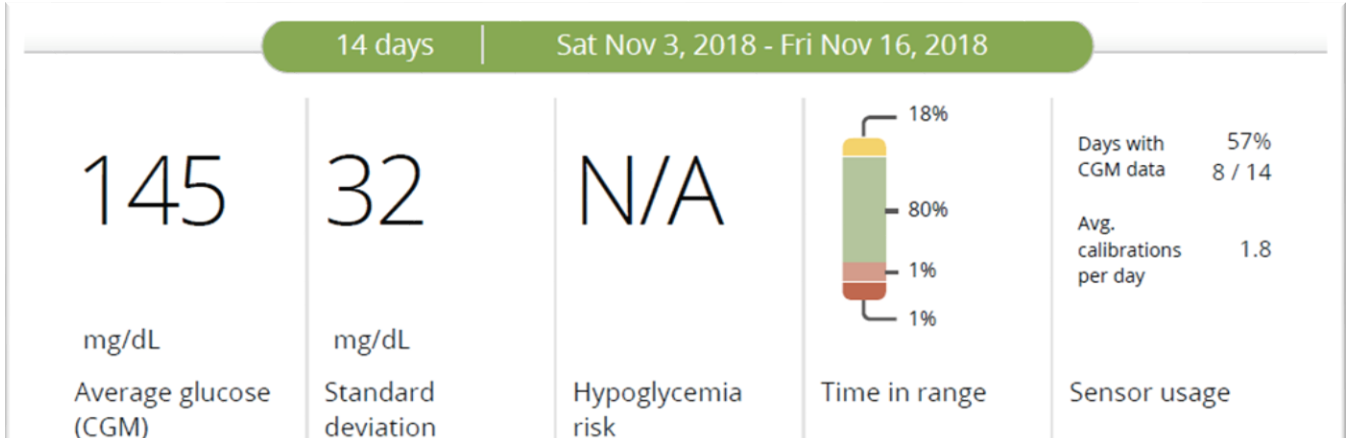
CGM as a therapeutic intervention
A1c 9.1% on SMBG

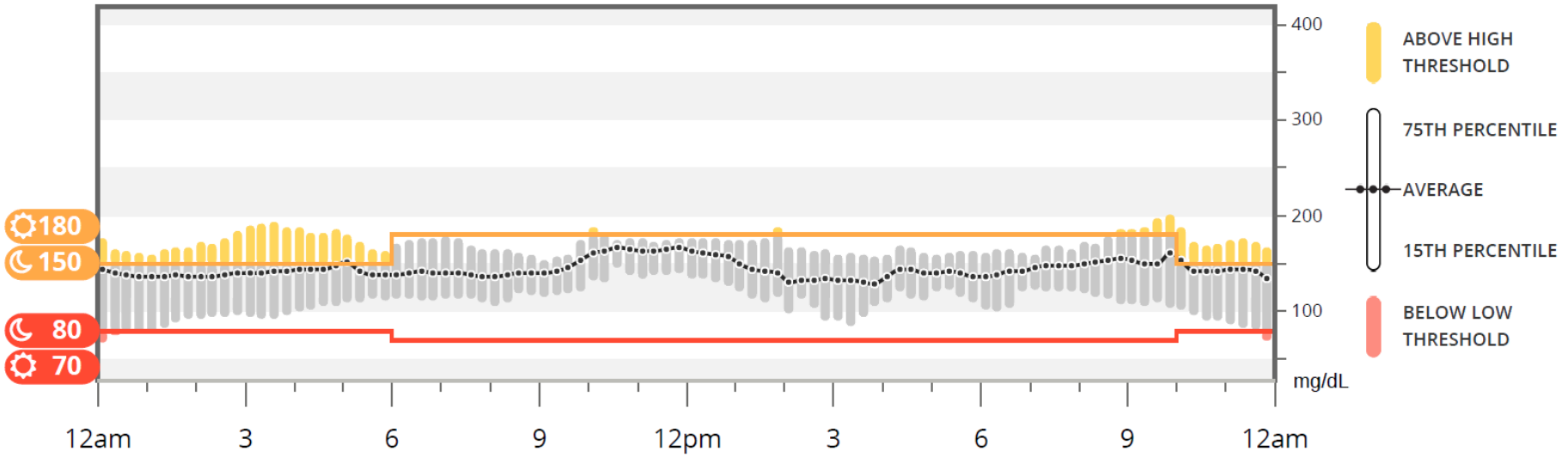
48 yo woman, BMI 46
Type 2 DM
Degludec 100 u bid
Humalog 75 u tid
Exenatide 2mg weekly



12 months after starting CGM
A1c 6.9%

48 yo woman, BMI 46
Type 2 DM
Degludec 100 u bid
Humalog 75 u tid
Exenatide 2mg weekly





Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - Accuracy & discrepancy with home glucometers
  - Available brands on the market & how to prescribe them
  - Clinical Utility
  - **How to analyze the data**
- Overview of over-the-counter CGM

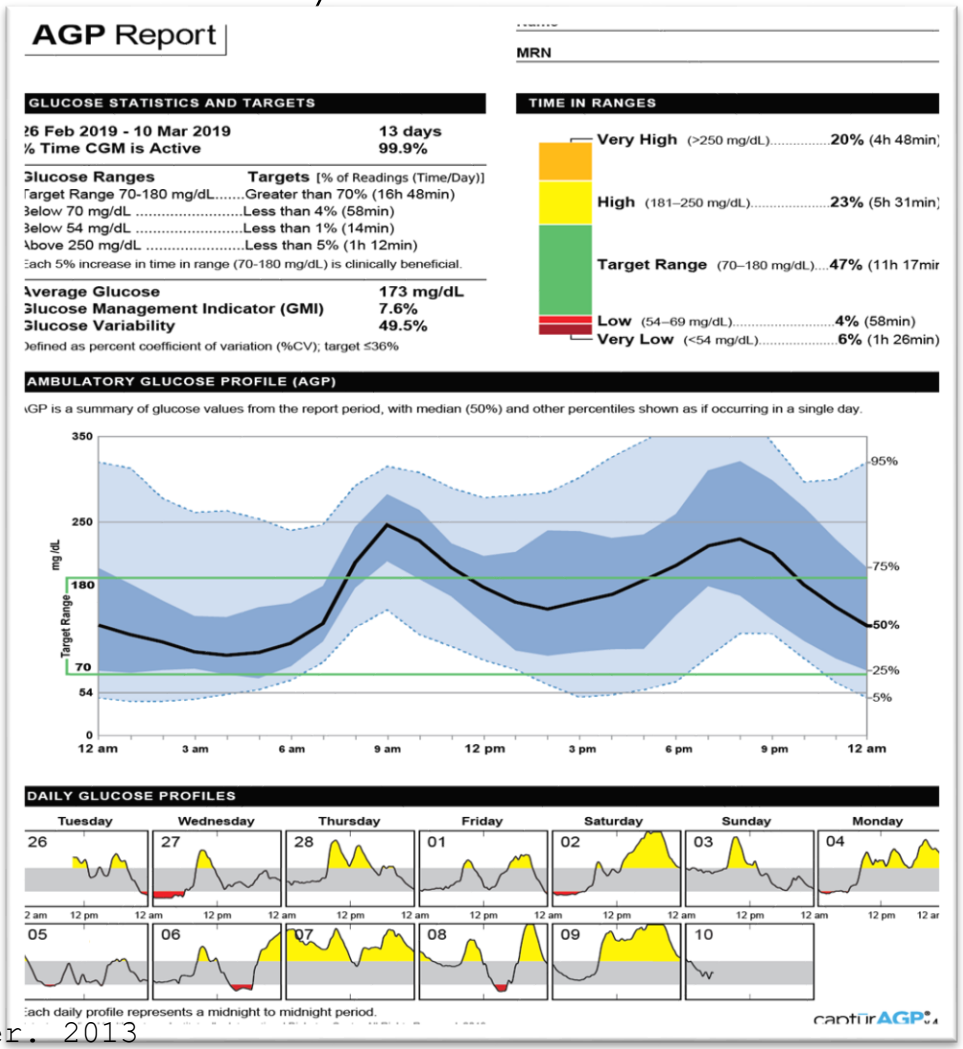
Ambulatory Glucose Profile (AGP) Report

*accessible by download or smartphone

Step 1: Review use, average glucose, & variability

Step 2: Evaluate Time in Range

Step 3: Look for trends in AGP



AGP Report

MRN

GLUCOSE STATISTICS AND TARGETS

26 Feb 2019 - 10 Mar 2019 — 13 days
% Time CGM is Active — 99.9%

Glucose Ranges — Targets [% of Readings (Time/Day)]
Target Range 70-180 mg/dL ..... Greater than 70% (16h 48min)
Below 70 mg/dL ..... Less than 4% (58min)
Below 54 mg/dL ..... Less than 1% (14min)
Above 250 mg/dL ..... Less than 5% (1h 12min)
Each 5% increase in time in range (70-180 mg/dL) is clinically beneficial.

Average Glucose — 173 mg/dL
Glucose Management Indicator (GMI) — 7.6%
Glucose Variability — 49.5%
Defined as percent coefficient of variation (%CV); target ≤36%

TIME IN RANGES

Very High (>250 mg/dL) 20% (4h 48min)
High (181–250 mg/dL) 23% (5h 31min)
Target Range (70–180 mg/dL) 47% (11h 17min)
Low (54–69 mg/dL) 4% (58min)
Very Low (<54 mg/dL) 6% (1h 26min)

AMBULATORY GLUCOSE PROFILE (AGP)

AGP is a summary of glucose values from the report period, with median (50%) and other percentiles shown as if occurring in a single day.

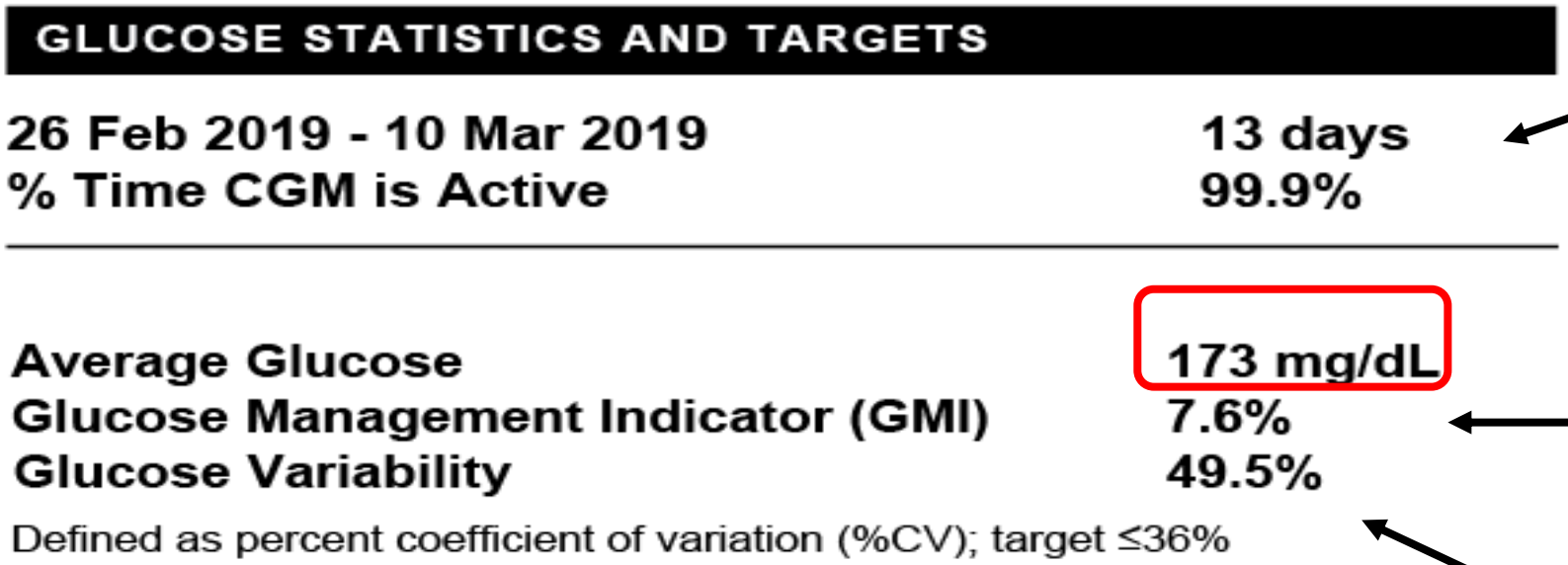
DAILY GLUCOSE PROFILES

Each daily profile represents a midnight to midnight period.

captureAGP

Bergenstal RM, et al. Diabetes Tech Ther. 2013
Battelin T, et al. Diabetes Care. 2019

Step 1: Review use, average glucose, & variability



GLUCOSE STATISTICS AND TARGETS

26 Feb 2019 - 10 Mar 2019	**13 days**
% Time CGM is Active	**99.9%**
Average Glucose	**173 mg/dL**
Glucose Management Indicator (GMI)	**7.6%**
Glucose Variability	**49.5%**

Defined as percent coefficient of variation (%CV); target ≤36%

Is the patient wearing the CGM?

Estimated A1c

Lower variability is better
%CV <36 or SD <50

Step 2: Time in Range (TIR)

% of day when glucose is 70-180 mg/dL

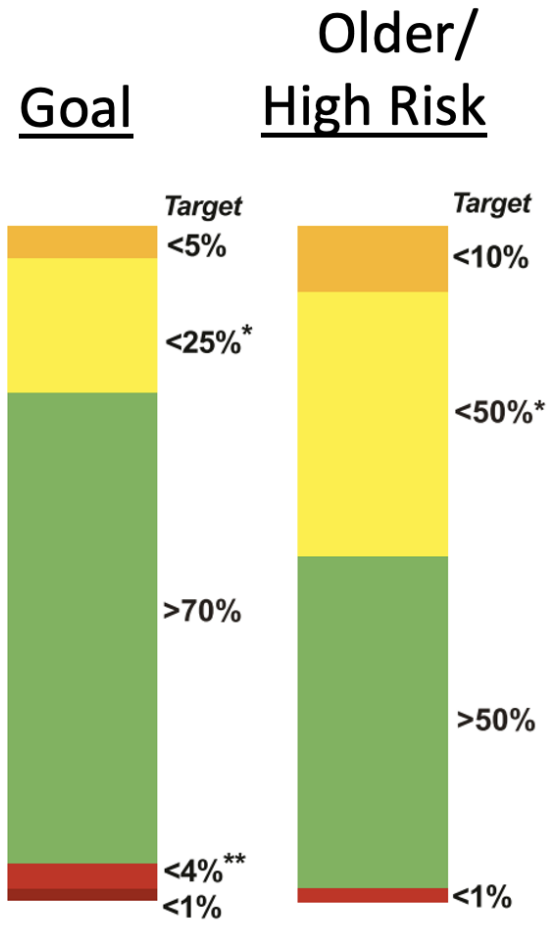
> 250 mg/dL

> 180 mg/dL

TIR = 70-180 mg/dL

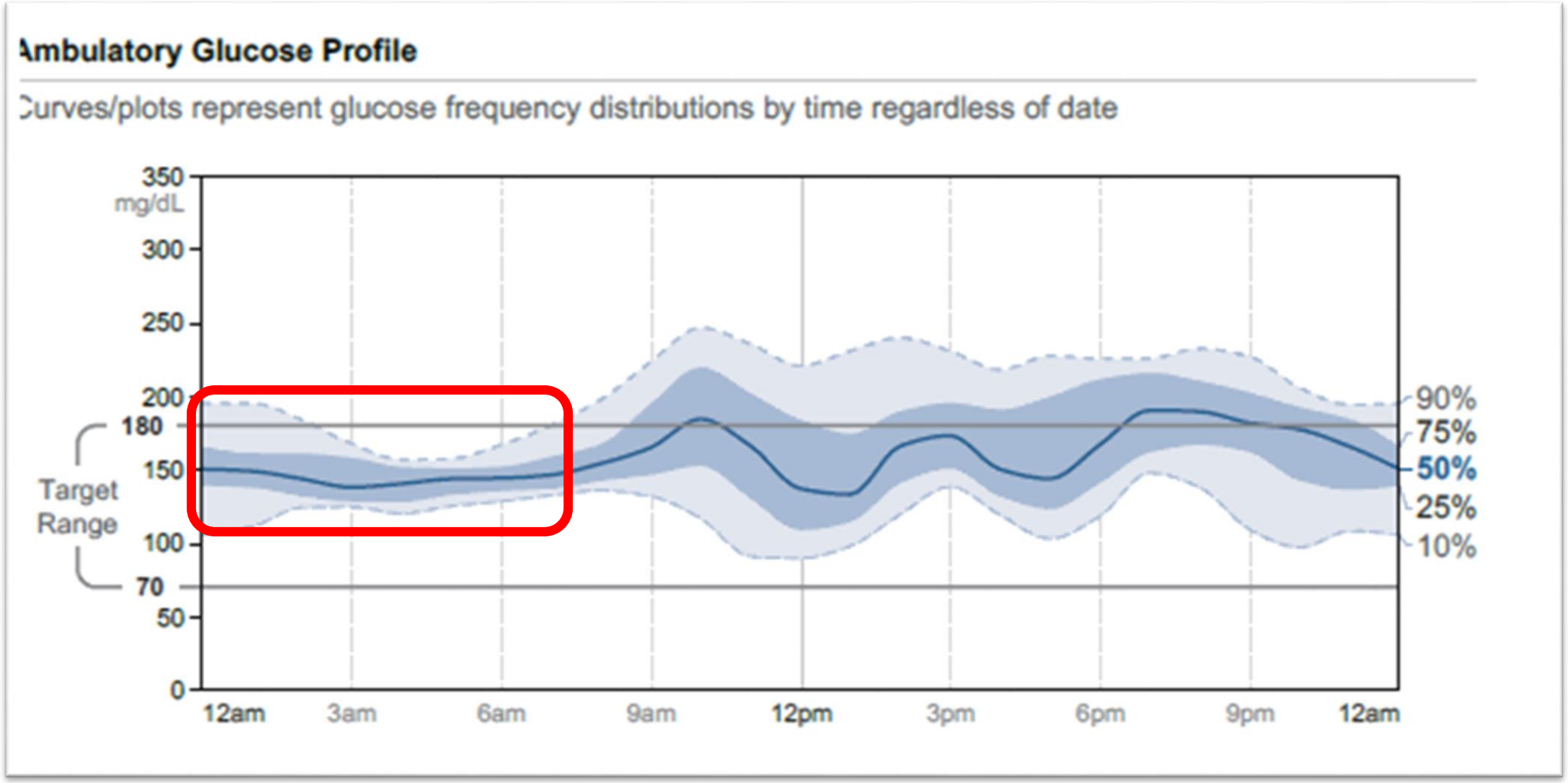
< 70 mg/dL

< 54 mg/dL



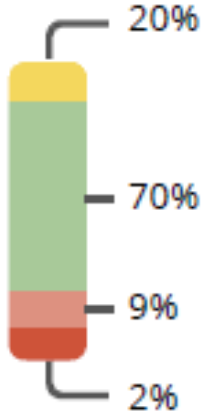
Battelin T, et al. Diabetes Care. 2019

Step 3 : Look for patters on AGP



AGP Report: Putting it all together

6.4 %	130	51	HIGH MODERATE **LOW** MINIMAL
Glucose Management Indicator	mg/dL Average glucose (CGM)	mg/dL Standard deviation (CGM)	Hypoglycemia risk



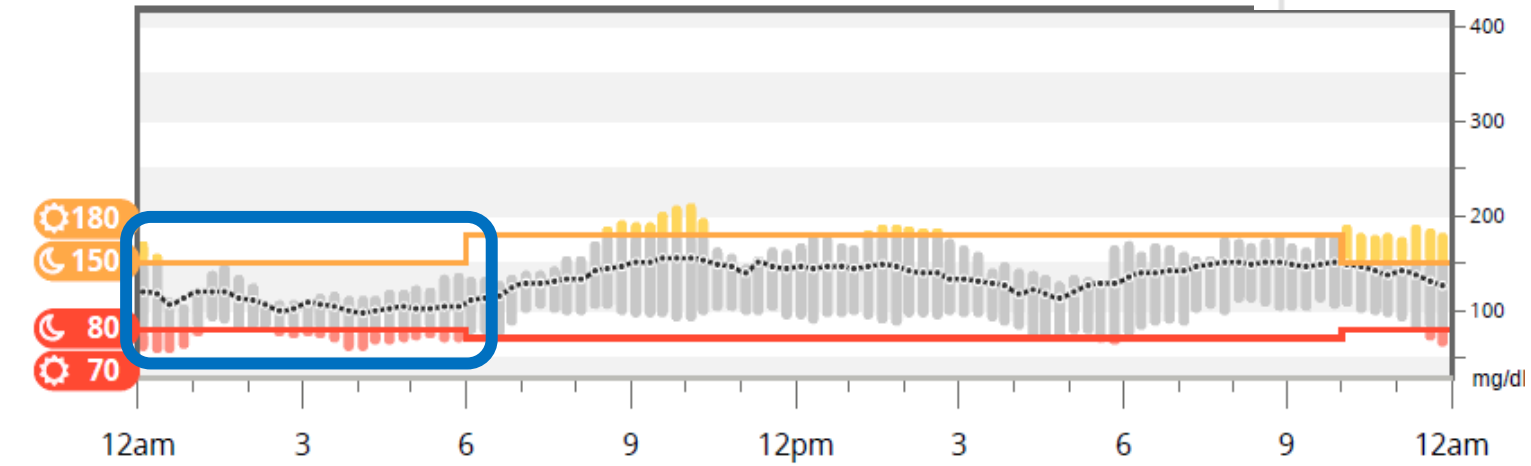
20% high

70% TIR

11% hypo

Time in range

This graph shows your data averaged over 14 days



78 yo, A1c 6/5% on metformin and glargine 10 units daily

Glucose Monitoring for Primary Care

- Utility and limitations of A1c and glucometer use
- Overview of continuous glucose monitors (CGM) for patients with diabetes
  - How they work
  - Accuracy & discrepancy with home glucometers
  - Available brands on the market & how to prescribe them
  - Clinical Utility
  - How to analyze the data
- **Overview of over-the-counter CGM**

Over-the-counter CGM

Dexcom Stelo

Freestyle Lingo

Freestyle Rio

Over-the-counter CGM

- Not approved to make medication adjust

	Dexcom Stelo	Abbott Lingo	Abbott Libre Rio
Who is it for?	DM2 not on insulin Prediabetes Anyone interested in tracking	People without diabetes Anyone looking to improve	DM2 not on insulin Prediabetes
How often is glucose presented?	15 min	1 min	1 min
Glucose range measured (mg/dL)	70-250	55-200	40-400
Wear time	15 days	14 days	15 days
Cost/month	$89-99	$83-98	$83-98
Alerts	“spike detection”	Detects events in	

Counseling patients on OTC CGM

- It is a tool, and not a perfect one, with limitations
- Look for trends in health patterns and how it may relate to glucose
  - Guilty pleasure foods
  - Exercise/activity
- People with/without diabetes/prediabetes may have glucose levels outside of normal range on occasion
- Recall that glucose can be “normal” <70 mg/dL if no symptoms (especially if not on glucose-lowering medication)

The Future of CGM

Dexcom/Oura partnership

Combined CGM-Continuous Ketone Monitoring

UC San Diego Health System

Inpatient CGM