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Four Clinical Cases Regarding the Estimation of Postprandial Plasma Glucose Upper-Bound Values from Sensor Measurements to Include both Different Stages of Initial Condition of Type 2 Diabetes and Hyperglycemic Control Efforts (GH-Method: Math-Physical Medicine)

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Abstract

The author developed his GH-Method: math-physical medicine (MPM) by applying mathematics, physics, engineering modeling, and computer science (big data analytics and AI) to derive the mathematical metabolism model. In this study, he utilized his MPM approach to investigate four clinical cases on the estimation of postprandial plasma glucose for the upper-bound values from sensor measurements along with the different stages of type 2 diabetes and hyperglycemic control.

Keywords: *Type 2 diabetes, metabolism, metabolic conditions, sensor measurements, lifestyle data, artificial intelligence, hyperglycemia control, and math-physical medicine.*

Introduction

This paper describes the calculation of the center height of a generalized postprandial plasma glucose (PPG) triangular geometry (i.e. average PPG value of simulated sensor glucose measurements) by including different baseline heights due to the combined effect from patient's type 2 diabetes (T2D) severity with pancreatic beta cells dysfunctional stages and hyperglycemia control efforts.

The GH-Method: Math-physical medicine (MPM) starts with the observation of the human body's physical phenomena (not biological or chemical characteristics), collecting elements of the disease related data (preferring big data), utilizing applicable engineering modeling techniques, developing appropriate mathematical equations (not just statistical analysis), and finally predicting the direction of the development and control mechanism of the disease.

Methods

For the purpose of this research, the author defines the following five different stages of the damaging impact from hyperglycemia which could lead to complications in T2D as described by different PPG mg/dL level.

Stage 1 (initial): PPG below 80

Stage 2 (light): PPG 80-100

Stage 3 (medium): PPG 100-120

Stage 4 (heavy): PPG 120-150

Stage 5 (severe): PPG above 150

The following simplified triangular geometry simulation for the sensor PPG prediction is developed based on a big data analytics of 1,215 PPG waveforms and 14,580 PPG sensor data collected by the author (Case A) from a period of 405 days (5/5/2018 - 6/13/2019).

Figure 1 depicts the generalized PPG waveform with its five key points and their corresponding PPG values. This triangular geometry has been further described in his previous publications (Reference 1: PPG-HOCA Model) and shown in Figure 2.

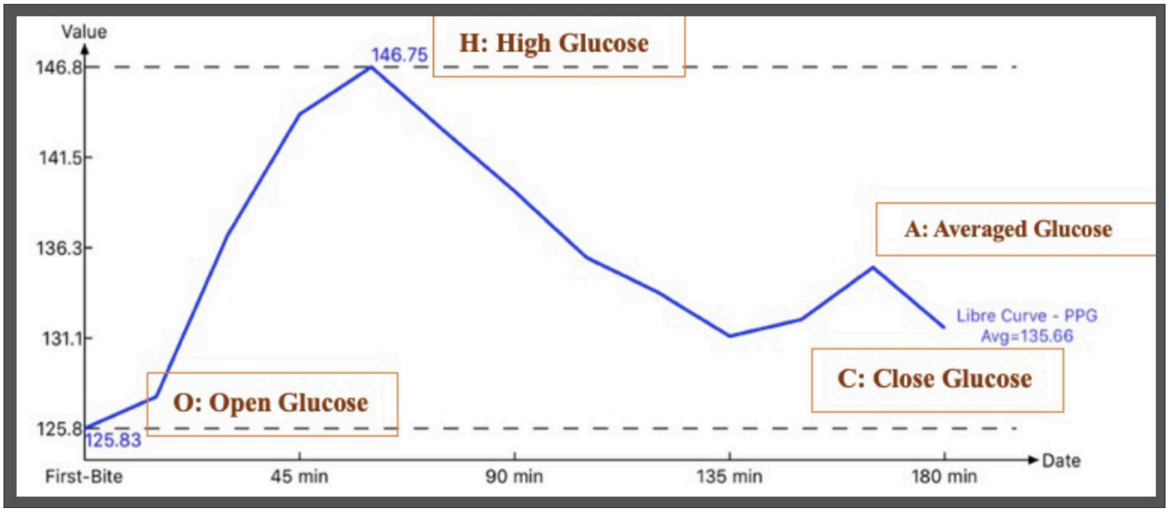
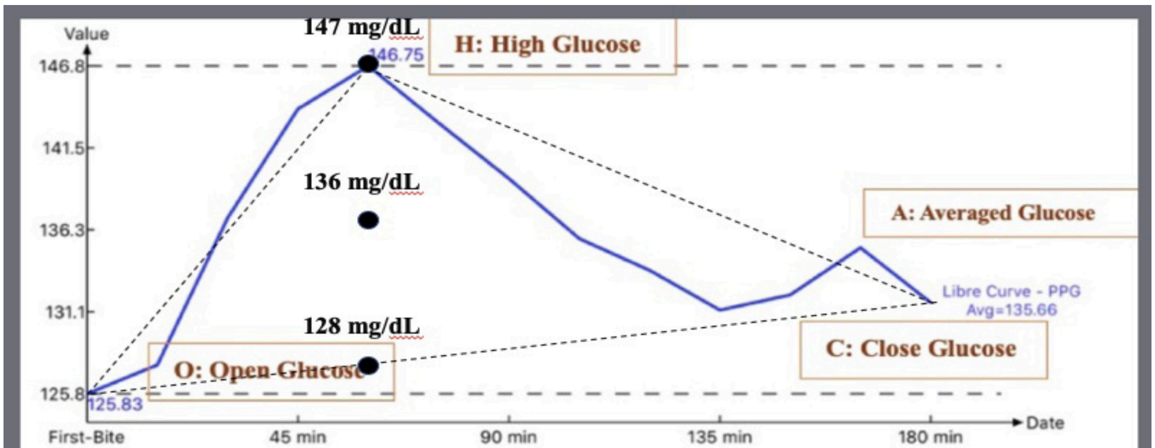


Fig 1. *Generalized PPG waveform with five key points*



From:	5/5/18	To:	6/10/19	Days:	401	Meals:	1258	PPG Waves:	1203
Open	High	O to H Time	Rise Speed	Close	H to C Time	Drop Speed	Sensor Avg	Finger Avg	Sensor / Finger
126	147	60	21	132	120	7.5	136	116	117%
mg/dL	mg/dL	minute	mg/dL per hour	mg/dL	minute	mg/dL per hour	mg/dL	mg/dL	
Open	High	H - O	Carbs/Sugar	PPG Rise Speed	H - C	Walking Steps (K)	PPG Drop Speed		
126	147	21	15.4	1.4	15	4.2	3.6		
mg/dL	mg/dL	mg/dL	gram	mg/dL per gram	mg/dL	K steps	mg/dL per K steps		

Fig 2. *Simplified PPG Triangular Geometry*

Here are the five key points based on their corresponding PPG values:

(1) B-open: Right endpoint of baseline with "Open glucose"

(2) B-close: Left endpoint of baseline with "Close glucose"

(3) B-mid: Baseline's "midpoint" at "1/3 distance from Open glucose"

(4) T-high: Top peak-point of triangle with "High glucose"

(5) C-average: Center point of triangle which is closed to the "Averaged sensor glucose"

It should be noted that the elevations of the baseline points, B-open and B-close, are based on a patient's T2D severity and different dysfunctional stage of the pancreatic beta cells. The B-midpoint is located at 1/3 distance from the Open glucose. This 1/3 location results from the actual observation of 1,215 PPG waveforms with their actual peak points occurring one hour after the first bite of food - not as traditionally thought of as *two hours after the first bite*.

Based on observed knowledge from ~30,000 big sensor data from Case A, the author further developed a simplified triangular geometry model to estimate "best-guessed" PPG values via sensor measurement for three other T2D patients.

Results and Discussion

Listed below are results from four clinical cases with different T2D severity and dysfunctional stage of the pancreatic beta cells (Figure 3):

(1) Case A (male 72 years old, 25 years diagnosed with T2D)

B-mid: 128 mg/dL, stage 4

Peak PPG: T-high: 147 mg/dL (Finger 118 mg/dL)

Average PPG (C-average): 136 mg/dL

(2) Case B (female 71 years old, 22 years diagnosed with T2D)

B-mid: 123 mg/dL, stage 4

Peak PPG: T-high: 141 mg/dL (Finger 113 mg/dL)

Average PPG (C-average): 131 mg/dL

(3) Case C (male 75 years old, 20 years diagnosed with T2D)

B-mid: 139 mg/dL, stage 5

Peak PPG: T-high: 192 mg/dL (Finger 154 mg/dL)

Average PPG (C-average): 164 mg/dL

(4) Case D (female 46 years old, 10 years diagnosed with T2D)

B-mid: 129 mg/dL, stage 4

Peak PPG: T-high: 166 mg/dL (Finger 133 mg/dL)

Average PPG (C-average): 148 mg/dL

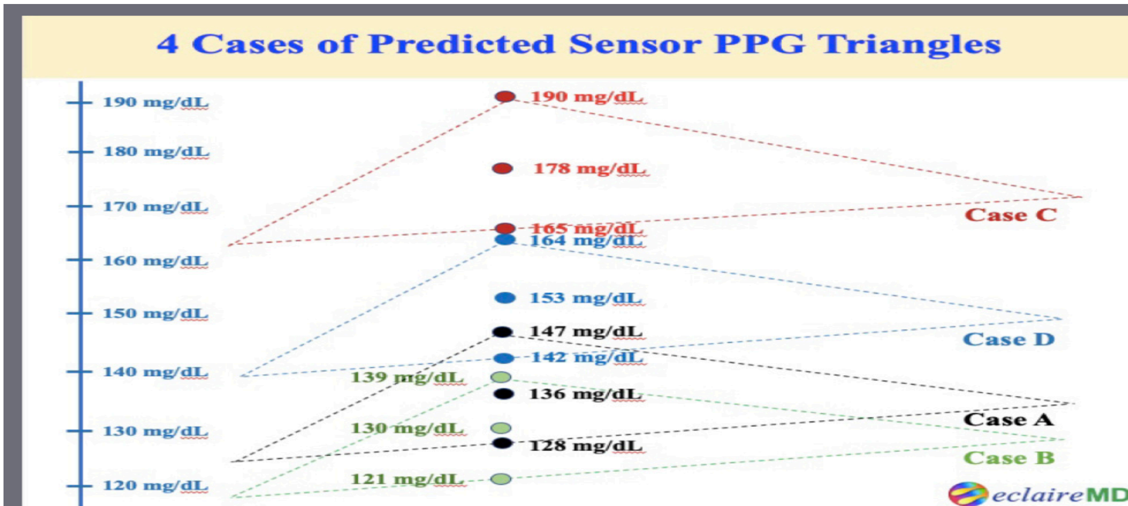
Case A had a severe stage 4 initial condition (suffered from five cardiac episodes and many other complications) but is the "best controlled" case due to his diligent and persistent lifestyle management program over the past five years.

Case B had a stage 3 initial condition (suffered from chest pain) and is a "quite-well controlled" case over a rather short period (6-months).

Case C probably also had a stage 4 or even stage 5 initial condition (suffered from a minor stroke) and is a "not-so-well controlled" case resulted from his low-carb diet but insufficient exercise (14-months).

Case D probably also had a stage 4 initial condition (was under heavy dosage of medications) and is a "quite-well controlled" case (9-months).

In summary, Case A is based on the actual data collected via both Finger and Sensor measurements. Due to various reasons, Cases B, C, and D have Finger measured PPG data only, without using sensor. Therefore, the author utilized Case A results to extend it into a "best-guessed" model to create their "most likely" upper bounds of glucose situations.



Case	Age	Gender	T2D (yrs)	Country	Stage	PPG Avg Finger	PPG-Sensor Base-Middle	PPG-Sensor Peak	PPG-Sensor Avg Sensor	Ratio 1 (Avg): Sensor/Finger	Ratio 2: Peak/Base	Ratio 3: Base/Finger	Sensor Values
A	72	Male	25	A	4	118	128	147	136	115%	115%	108%	Measured
B	71	Female	22	A	4	113	121	139	130	115%	115%	107%	Guessed
C	75	Male	20	T	5	154	165	190	178	115%	115%	107%	Guessed
D	46	Female	10	M	4	133	142	164	153	115%	115%	107%	Guessed

Fig 3. *Case A, B, C, and D*

Conclusions

Currently, continuous glucose monitoring sensor device has not yet gain momentum. In addition, there are always fewer patients who have strong will-power, desire, and persistence on measuring and recording their daily data of food, exercise, and glucose values. Therefore, the author utilized his own collected big data as the foundation to further develop an AI algorithms with machine-learning, self-judging, and auto-correction capabilities for other patients.

This paper describes a simplified yet quite accurate approach to predict another aspect of PPG waveforms for T2D patients via Sensor. This "quick-but-not-so-dirty" triangular geometry method based on big data analytics and artificial intelligence can serve as a practical tool for T2D patients to learn more about their realistic diabetes situations in order to better control their conditions. At a later time, the author will develop an algorithm for a better estimated HbA1C value which includes influences from both traditional finger-measured glucoses and lately available sensor monitored glucoses, or even the author developed best-guessed sensor glucoses.

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