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Research Article

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Various Conversion Factors of Estimated Average Glucose or eAG and HbA1C Based on GH-Method: Math-Physical Medicine (No. 486)

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Abstract

Since 7/1/2015, the author initiated his stringent diabetes management via carbs/sugar intake amount and post-meal walking exercise. As a result, his type 2 diabetes (T2D) conditions became quickly under control, where he was able to discontinue all diabetes medications by 12/8/2015. Starting on 1/1/2016, his glucose values have not been impacted by any external influences such as chemical elements from diabetes medications or biological components of insulin injections; therefore, his T2D control has been entirely based on his rigorous lifestyle management from this date.

Since 1/1/2012, he has collected the finger pierced glucose data 4 times daily, once in early morning for fasting plasma glucose (FPG), and three times at two-hours after his first-bite of meals for postprandial plasma glucose (PPG). He then developed and utilized an HbA1C prediction model with a conversion factor known as finger-CF for finger eAG/A1C on 1/1/2016.

However, starting from 5/5/2018, along with his collected finger glucose measurement data, he has been collecting 96 glucose data each day using a continuous glucose monitoring (CGM) sensor device. Based on his collected CGM sensor glucoses, he created additional HbA1C prediction models with a conversion factor known as sensor-CF for his sensor eAG/A1C.

In addition, he developed a hybrid model which includes both finger glucoses and sensor glucoses i.e., (finger+sensor)/2 and assigned a different conversion factor known as hybrid-CF for his hybrid eAG/A1C on 5/5/2018.

There are two important time periods being utilized in this study. The first longer period from 1/1/2016 to 7/30/2021 does not have any related bio-chemical compounds in his body and organs. The second shorter period from 8/5/2018 to 7/30/2021 contains a complete dataset of his collected sensor glucoses.

By using the first period of 5.5 years, he compares his average A1C values, including finger A1C, sensor A1C, and hybrid A1C, against his average A1C measured from his 28 lab-tests during the period of 66 months. By using the second period of 3 years, he compares his average A1C values, including finger A1C, sensor A1C, and hybrid A1C, against his average A1C measured from his 12 lab-tests during the period of 36 months.

Both glucose and HbA1C involve many influential factors. Although the majority institutions are using the ***American Diabetes Association (ADA) defined conversion formula i.e., eAG=28.7*A1C-46.7,*** there are other definitions in the diabetes community. For example, ***Perinatology uses the conversion formula of eAG=35.6*A1C-77.3*** that produces a different set of eAG values corresponding to the same A1C levels by using the ADA formula. Therefore, it is safe to assume that the medical community still lacks a precise definition for the term HbA1C mathematically. In general, the medical community loosely defines HbA1C as being the 90-days average glucose value. However, the actual life-span of red blood cells (RBC) range between 90 to 120 days, where some documents even stated as 115 days. Based on this knowledge, the author of this paper developed a daily finger A1C model using 120 days glucoses with various weighted-contribution factors for each month. He installed this program on his iPhone for his daily use which would generate slightly different A1C values from this research paper.

In reality, a lab-tested HbA1C is also affected by many other non-biomedical influential factors, including but not limited to, its operational procedures, possible human errors, testing environment differences (even the altitude of the laboratory), etc.

The objective of this research is hopefully to identify some highly accurate CF values for different glucose collection cases including finger case, sensor case, and hybrid case. His purpose is to identify one CF for each case which will be easier to remember and apply on his future T2D control efforts.

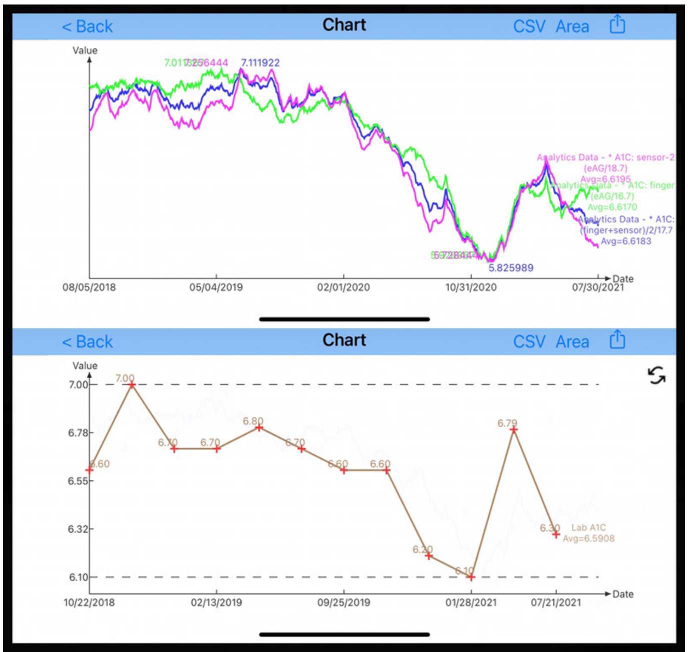
In conclusion, he has identified three easy-to-remember conversion factors: ***16.7 for finger glucose case, 18.7 for sensor***

glucose case, and 17.7 for hybrid glucose case. All three CF values resulted in 100% prediction accuracy, ***with A1C values of 6.6%, both measured and predicted***, against the lab-tested HbA1C.

His objective is not only to provide a set of simple and easy-to-remember formulas or CF of 16.7, 17.7, & 18.7, which are highly accurate for converting the daily glucose values (eAG) into predicted daily HbA1C values. Furthermore, his A1C prediction models can also be useful for many other patients to achieve their daily diabetes control. If we can predict the future outcomes of A1C on a daily basis accurately, then our diabetes control will not be a difficult task. For example, the author is carrying a pocket-size card (Figure 6) which provides easy access to sensor-eGA/A1C conversion values for his daily diabetes control effort.

He spends time and efforts on developing several highly accurate HbA1C prediction models in order to provide an "early and preventive warning" to diabetes patients on a daily basis. Therefore, they do not have to wait until the actual lab-test day to know their HbA1C value. By that time, it would be too late to do anything or to make any modifications for their past behaviors and lifestyle details.

The author strongly believes that an accurate prediction offers a better chance in preventing the disease, which is always superior to treating it, including medications, injections, surgeries, chemotherapy, or radiation.



7/31/21	Normal										
HbA1C value	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
ADA: eAG=28.7*A1C-46.7	97	100	103	105	108	111	114	117	120	123	126
Perinatology: eAG=35.6*A1C-77.3	101	104	108	111	115	119	122	126	129	133	136
Hsu-finger: eAG = 16.7*A1C	84	85	87	89	90	92	94	95	97	99	100
Hsu-sensor: eAG = 18.7*A1C	94	95	97	99	101	103	105	107	108	110	112
Hsu-hybrid: eAG = 17.7*A1C	89	90	92	94	96	97	99	101	103	104	106
7/31/21	Pre-diabetes				Diabetes						Avg
HbA1C value	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	6.0
ADA: eAG=28.7*A1C-46.7	97	100	103	105	108	111	114	117	120	123	126
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Hsu-finger: eAG = 16.7*A1C	84	85	87	89	90	92	94	95	97	99	100
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Hsu-hybrid: eAG = 17.7*A1C	89	90	92	94	96	97	99	101	103	104	106

7/31/21	Normal				Pre-Diabetes		Diabetes				Severe Diabetes	
Hsu Sensor A1C: eAG = 18.7 * A1C	A1C	eAG	A1C	eAG	A1C	eAG	A1C	eAG	A1C	eAG	A1C	eAG
	5.0	94	5.5	103	6.0	112	6.5	122	7.0	131	8.0	150
	5.1	95	5.6	105	6.1	114	6.6	123	7.1	133	8.1	151
	5.2	97	5.7	107	6.2	116	6.7	125	7.2	135	8.2	153
	5.3	99	5.8	108	6.3	118	6.8	127	7.3	137	8.3	155
	5.4	101	5.9	110	6.4	120	6.9	129	7.4	138	8.4	157

Introduction

Since 7/1/2015, the author initiated his stringent diabetes management via carbs/sugar intake amount and post-meal walking exercise. As a result, his type 2 diabetes (T2D) conditions became quickly under control, where he was able to discontinue all diabetes medications by 12/8/2015. Starting on 1/1/2016, his glucose values have not been impacted by any external influences such as chemical elements from diabetes medications or biological components of insulin injections; therefore, his T2D control has been entirely based on his rigorous lifestyle management from this date.

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In addition, he developed a hybrid model which includes both finger glucoses and sensor glucoses i.e., (finger+sensor)/2 and assigned a different conversion factor known as hybrid-CF for his hybrid eAG/A1C on 5/5/2018.

There are two important time periods being utilized in this study. The first longer period from 1/1/2016 to 7/30/2021 does not have any related bio-chemical compounds in his body and organs. The second shorter period from 8/5/2018 to 7/30/2021 contains a complete dataset of his collected sensor glucoses.

By using the first period of 5.5 years, he compares his average A1C values, including finger A1C, sensor A1C, and hybrid A1C, against his average A1C measured from his 28 lab-tests during the period of 66 months. By using the second period of 3 years, he compares his average A1C values, including finger A1C, sensor A1C, and hybrid A1C, against his average A1C measured from his 12 lab-tests during the period of 36 months.

Both glucose and HbA1C involve many influential factors. Although the majority institutions are using the ***American Diabetes Association (ADA) defined conversion formula i.e., eAG=28.7*A1C-46.7,*** there are other definitions in the diabetes community. For example, ***Perinatology uses the conversion formula of eAG=35.6*A1C-77.3*** that produces a different set of eAG values corresponding to the same A1C levels by using the ADA formula. Therefore, it is safe to assume that the medical community still lacks a precise definition for the term HbA1C mathematically. In general, the medical community loosely defines HbA1C as being the 90-days average glucose value. However, the actual life-span of red blood cells (RBC) range between 90 to 120 days, where some documents even stated as 115 days. Based on this knowledge, the author of this paper developed a daily finger A1C model using 120 days glucoses with various weighted-contribution factors for each month. He installed this program on his iPhone for his daily use which would generate slightly different A1C values from this research paper.

In reality, a lab-tested HbA1C is also affected by many other non-biomedical influential factors, including but not limited to, its operational procedures, possible human errors, testing environment differences (even the altitude of the laboratory), etc.

The objective of this research is hopefully to identify some highly accurate CF values for different glucose collection cases including finger case, sensor case, and hybrid case. His purpose is to identify one CF for each case which will be easier to remember and apply on his future T2D control efforts.

Method

Using signal processing techniques, the author identified more than 20 influential factors of physical behaviors for glucose. From these 20+ factors, he further outlined the following six most prominent conclusions for his glucose and HbA1C values:

1. The CGM sensor based A1C variances have the following contributions: 29% from FPG, 38% from PPG, and 33% from between-meals and pre-bedtime periods. Therefore, ***all three segments contributed to the HbA1C value almost equally (approximately one-third each).***
2. FPG variance due to weight change with ~77% contribution.
3. Colder weather impact on FPG with a decrease of each Fahrenheit degree caused 0.3 mg/dL decrease of FPG.
4. PPG variance due to carbs/sugar intake with ~39% weighted contribution on PPG.
5. PPG variance due to post-meal walking with ~41% weighted contribution on PPG.
6. Warm weather impact on PPG with an increase of each Fahrenheit degree caused 0.9 mg/dL increase of PPG.

It is common knowledge that HbA1C is closely connected to the average glucose for the past 90 days. Actually, the average human RBCs, after differentiating from erythroblasts in the bone marrow, are released into the blood and survive in circulation for approximately 115 days. The author has adopted the 120-days finger glucose model with different weight-factor for each month. In addition, he uses the CGM collected average sensor glucose (eAG) data with the daily glucose fluctuation data for this HbA1C study. It should be reemphasized that the lab-tested HbA1C value should not be considered as the “golden standard” since it contains a large margin of error due to various possible causes.

Here, he is listing his three arithmetic equations to be used for the predicted HbA1C. These three predicted HbA1C formulas with three associated CF are listed as follows:

(a) Finger A1C = (finger eAG) / 16.7
(b) Sensor A1C = (sensor eAG) / 18.7
(c) Hybrid A1C =
(finger eAG + sensor eAG) / 17.7

The CF values of ***16.7 for finger, 17.7 for hybrid, and 18.7 for sensor*** *are selected to achieve high prediction accuracy and could vary from patient to patient or from one time period to another time period. This CF value is dependent on significant changes occurring in certain time period or for a particular patient with some special health conditions. However, for a general application purpose, they do not vary too much for the author’s case.*

Results

This paper is a simple demonstration of 3 predicted A1C models that achieved 100% prediction accuracy in comparison against the average lab-tested results of 12 A1C values during a 3-year timeframe from 8/8/2018 to 7/30/2021. In addition, the author compares the lab-tested A1C vs. the software calculated finger A1C over a shorter 3-year period and a longer 5.5-year period. He has written many diabetes papers regarding HbA1C. If readers are interested in learning more about this subject, they can visit the author’s website at: www.eclairemd.com.

Figure 1 reflects the predicted A1C results including finger, sensor, and hybrid in comparison with his average 12 lab-tested A1C value. Through trial-and-error adjustment method, he discovers that the set of three CF values of 16.7 for finger, 18.7 for sensor, and 17.7 for hybrid would deliver identical A1C results of 6.6% over a long period.

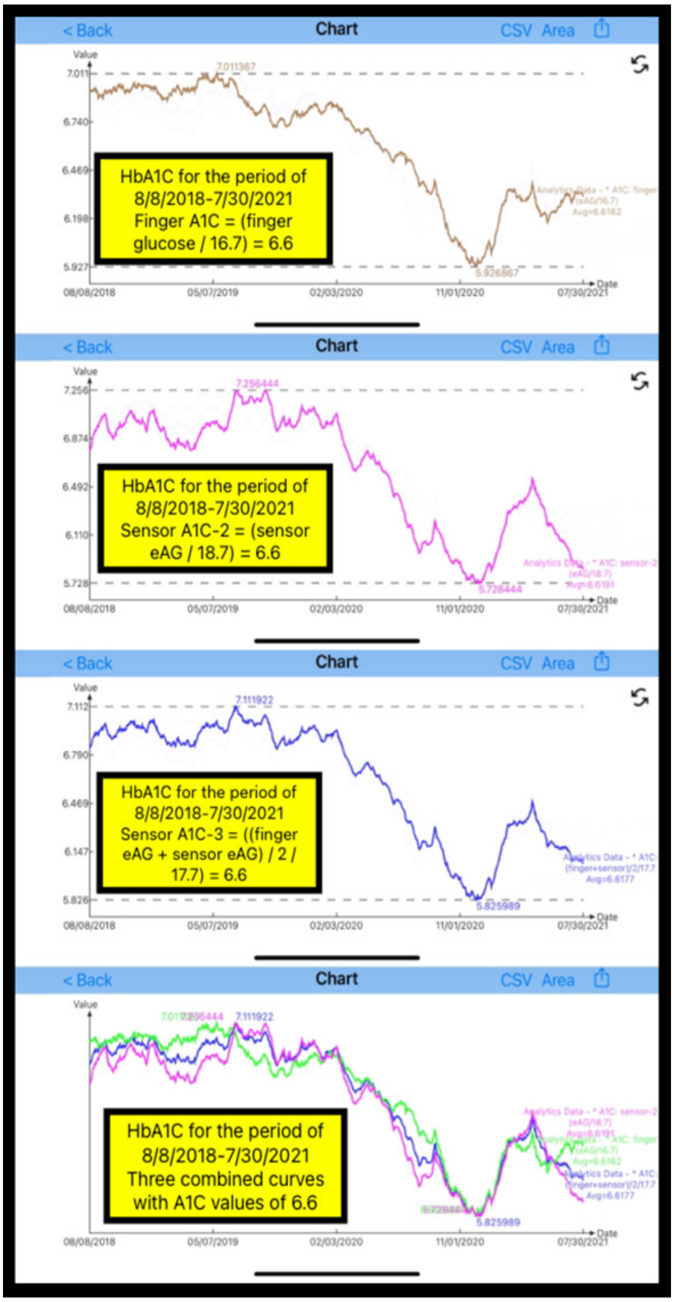

Figure 1: Three predicted A1C models, finger, sensor, and hybrid

The following three equations are used in Figure 1:

(a) Finger A1C = (finger eAG) / 16.7
(b) Sensor A1C = (sensor eAG) / 18.7
(c) Hybrid A1C =
(finger eAG + sensor eAG) / 17.7

They produce the following A1C results:

Lab A1C: ***6.6%***
Finger A1C: ***6.6%***
Sensor A1C: ***6.6%***
Hybrid A1C: ***6.6%***

Figure 2 illustrates three predicted A1C curves combined in one diagram, along with his 12 lab-tested A1C values over a 36-month period, and his software calculated finger A1C results for the shorter period of 8/8/2018 - 7/30/2021.

It should be pointed out that his software calculated finger A1C uses the 120-days Glucose model with four different assigned monthly weighted-factor. This software calculated finger A1C Model has yielded a slightly lower average A1C value of 6.5% which has 98.5% of prediction accuracy in comparison with the average lab-tested A1C result of 6.6%.

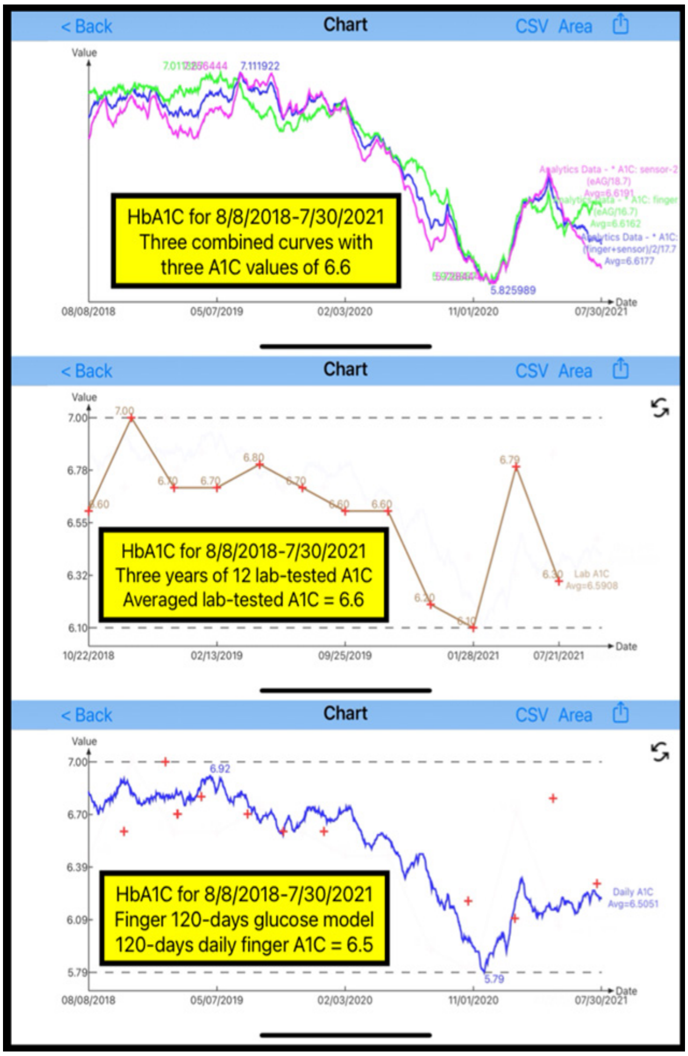

Figure 2: Three predicted A1C curves, 12 lab-tested A1C values and software calculated finger A1C for the period of 8/8/2018 - 7/30/2021

Figure 3 depicts the comparison between a longer period of 5.5 years (1/1/2016 - 7/30/2021) with 28 lab-tests within 66 months versus a shorter period of 3 years (8/8/2018 - 7/30/2021) with 12 lab-tests within 36 months of both lab-tested A1C vs. software calculated finger A1C. The results are summarized below in the format of (lab-testedA1C, software calculated finger A1C):

Shorter period: (6.58%, 6.52%)
Longer period: (6.59%, 6.74%)

Figure 3: Long period of 5.5 years versus short period of 3 years of both lab-tested A1C vs. software calculated finger A1C

In conclusion, through carefully selected appropriate CF of ***16.7 for finger A1C, 18.7 for sensor A1C,*** *and 17.7 for hybrid A1C, his three predicted HbA1C models are able to offer 100% prediction accuracy in comparison against the lab-tested A1C of 6.6% over a period of 3 years from 8/8/2018 to 7/30/2021.*

Figure 4 reveals his calculated eAG values corresponding to a specific HbA1C value within the range of 5.0% to 7.0%, at an interval of 0.1%.

7/31/21	Normal											
HbA1C value	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	
ADA: eAG=28.7*A1C-46.7	97	100	103	105	108	111	114	117	120	123	126	
Perinatology: eAG=35.6*A1C-77.3	101	104	108	111	115	119	122	126	129	133	136	
Hsu-finger: eAG = 16.7*A1C	84	85	87	89	90	92	94	95	97	99	100	
Hsu-sensor: eAG = 18.7*A1C	94	95	97	99	101	103	105	107	108	110	112	
Hsu-hybrid: eAG = 17.7*A1C	89	90	92	94	96	97	99	101	103	104	106	
7/31/21	Pre-diabetes				Diabetes						Avg	
HbA1C value	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	6.0	
ADA: eAG=28.7*A1C-46.7	97	100	103	105	108	111	114	117	120	123	126	
Perinatology: eAG=35.6*A1C-77.3	101	104	108	111	115	119	122	126	129	133	136	
Hsu-finger: eAG = 16.7*A1C	84	85	87	89	90	92	94	95	97	99	100	
Hsu-sensor: eAG = 18.7*A1C	94	95	97	99	101	103	105	107	108	110	112	
Hsu-hybrid: eAG = 17.7*A1C	89	90	92	94	96	97	99	101	103	104	106	
7/31/21	Normal				Pre-Diabetes		Diabetes				Severe Diabetes	
Hsu Sensor A1C: eAG = 18.7 * A1C	A1C	eAG	A1C	eAG	A1C	eAG	A1C	eAG	A1C	eAG	A1C	eAG
	5.0	94	5.5	103	6.0	112	6.5	122	7.0	131	8.0	150
	5.1	95	5.6	105	6.1	114	6.6	123	7.1	133	8.1	151
	5.2	97	5.7	107	6.2	116	6.7	125	7.2	135	8.2	153
	5.3	99	5.8	108	6.3	118	6.8	127	7.3	137	8.3	155
	5.4	101	5.9	110	6.4	120	6.9	129	7.4	138	8.4	157

Figure 4: Calculated data of eAG/A1C conversion using 5 formulas from ADA, Perinatology, Hsu-finger, Hsu-sensor, and Hsu-hybrid

This figure contains the following 5 formulas:

ADA eAG =28.7*A1C-46.7
Perinatology eAG =35.6*A1C-77.3
Hsu-finger eAG =16.7*A1C
Hsu-sensor eAG =18.7*A1C
Hsu-hybrid eAG =17.7*A1C

Figure 5 shows a pocket-size card with indication of different sensor-eAG levels and their corresponding A1C levels.

HbA1C	eAG	HbA1C	eAG
Hsu Sensor A1C = eAG/18.7			
5.0	94	6.0	112
5.1	95	6.1	114
5.2	97	6.2	116
5.3	99	6.3	118
5.4	101	6.4	120
5.5	103	6.5	122
5.6	105	6.6	123
5.7	107	6.7	125
5.8	108	6.8	127
5.9	110	6.9	129
6.0	112	7.0	131

Figure 5: A pocket-sized card carried by the author for his daily sensor-eAG to A1C conversion

Conclusion

In conclusion, he has identified three easy-to-remember conversion factors: 16.7 for finger glucose case, 18.7 for sensor glucose case, and 17.7 for hybrid glucose case. All three CF values resulted in 100% prediction accuracy, with A1C values of 6.6%, both measured and predicted, against the lab-tested HbA1C.

His objective is not only to provide a set of simple and easy-to-remember formulas or CF of 16.7, 17.7, & 18.7, which are highly accurate for converting the daily glucose values (eAG) into predicted daily HbA1C values. Furthermore, his A1C prediction models can also be useful for many other patients to achieve their daily diabetes control. If we can predict the future outcomes of A1C on a daily basis accurately, then our diabetes control will not be a difficult task. For example, the author is carrying a pocket-size card (Figure 6) which provides easy access to sensor-eGA/A1C conversion values for his daily diabetes control effort.

He spends time and efforts on developing several highly accurate HbA1C prediction models in order to provide an "early and preventive warning" to diabetes patients on a daily basis. Therefore, they do not have to wait until the actual lab-test day to know their HbA1C value. By that time, it would be too late to do anything or to make any modifications for their past behaviors and lifestyle details.

The author strongly believes that an accurate prediction offers a better chance in preventing the disease, which is always superior to treating it, including medications, injections, surgeries, chemotherapy, or radiation.

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