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Research Article

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Continuous Glucose Monitoring sensor glucose data analysis of Time in Range, Time Above Range, and Time Below Range for 4 annual mean values based on GH-Method: math-physical medicine (No. 507)

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Abstract

The author applies data pattern and curve trend analysis tools using his collected continuous glucose monitoring (CGM) sensor data over ~4-year period from 5/8/2018 to 9/5/2021. He further divides this long period into 4 annual sub-periods of 2018, 2019, 2020, and 2021 in order to investigate the annual differences of his glucose control situation. Special attention has been placed on applying the American Diabetes Association (ADA) 2020 Guidelines for Time In Range (TIR) % with TIR average glucose values between 70 mg/dL and 180 mg/dL, Time Above Range (TAR) % with TAR average glucose value above 180 mg/dL, and Time Below Range (TBR) % with TBR average glucose value below 70 mg/dL.

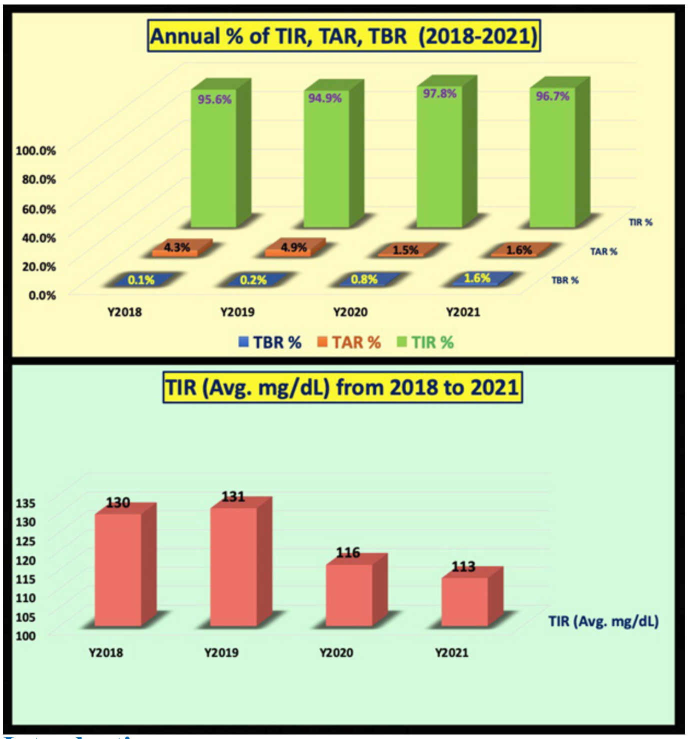
With emphasis placed on TIR, instead of TAR or TBR, since TIR occupies the majority of his collected glucose data which indicates his T2D control situation.

In summary, there are three key findings from this study:

(1) ***TIR:*** *Over the past 4 years, his TIR percentages are above 94% and the average TIR values are below 131 mg/dL, along with an average TBR percentages below 1.6% and an averaged TAR percentages below 4.9%. This means that* ***his T2D is well under control with the majority (>94.9%) of glucoses within a reasonable and "acceptable" range.*** *The risks probability of having hypoglycemia are below 1.6%, and his hyperglycemic risk probabilities are below 4.9%.*

(2) The lower TIR percentages and higher average eAG values over the period of 2018-2019 show that ***his T2D control is in better condition over the period of 2020-2021*** *(peaceful and routine lifestyle due to COVID quarantine)* ***than the period of 2018-2019*** *(heavy travel lifestyle to attend many medical conferences).*

(3) This analysis only provides a "macro-view" of his T2D control; however, ***he needs to identify a "micro-view".*** *Both TIR and HbA1C provide the overview or the mean value of glucose situations. In other words,* ***he needs additional research to gain a better understanding for the "shell of TIR"****. This will be another topic in future research projects.*



Introduction

The author applies data pattern and curve trend analysis tools using his collected continuous glucose monitoring (CGM) sensor data over ~4-year period from 5/8/2018 to 9/5/2021. He further divides this long period into 4 annual sub-periods of 2018, 2019, 2020, and 2021 in order to investigate the annual differences of his glucose control situation. Special attention has been placed on applying the American Diabetes Association (ADA) 2020 Guidelines for Time In Range (TIR) % with TIR average glucose values between 70 mg/dL and 180 mg/dL, Time Above Range (TAR) % with TAR average glucose value above 180 mg/dL, and Time Below Range (TBR) % with TBR average glucose value below 70 mg/dL.

With emphasis placed on TIR, instead of TAR or TBR, since TIR occupies the majority of his collected glucose data which indicates his T2D control situation.

Methods

MPM Background

To learn more about the author's developed GH-Method: math-physical medicine (MPM) methodology, readers can read the following three papers selected from the published 400+ medical research articles.

The first paper, No. 386, describes his MPM methodology in a general conceptual format. The second paper, No. 387, outlines the history of his personalized diabetes research, various application tools, and the differences between biochemical medicine (BCM) approach versus the MPM approach. The third paper, No. 397, depicts a general flow diagram containing ~10 key MPM research methods and different tools.

All of listed papers in the section of references are from his written and published medical research articles.

The Author'S Case of Diabetes and Complications

The author has been a severe T2D patient since 1996. He weighed 220 lb. (100 kg, BMI 32.5) at that time. By 2010, he still weighed 198 lb. (BMI 29.2) with an average daily glucose of 250 mg/dL (HbA1C of 10%). During that year, his triglycerides reached to 1161 (diabetic retinopathy, DR) and albumin-creatinine ratio (ACR) at 116 (chronic kidney diseases, CKD). He also suffered from five cardiac episodes within a decade. In 2010, three independent physicians warned him regarding his needs of kidney dialysis treatment and his future high risk of dying from his severe diabetic complications. Other than cerebrovascular disease (stroke), he has suffered most of known diabetic complications, including both macro-vascular and micro-vascular complications.

In 2010, he decided to launch his self-study on endocrinology, diabetes, and food nutrition in order to save his own life. During 2015 and 2016, he developed four prediction models related to diabetes conditions: weight, postprandial plasma glucose (PPG), fasting plasma glucose (FPG), and A1C. As a result, from using his developed mathematical metabolism index (MI) model in 2014 and the four prediction tools, by end of 2016, his weight was reduced from 220 lbs. (100 kg, BMI 32.5) to 176 lbs. (89 kg, BMI 26.0), waistline from 44 inches (112 cm, nonalcoholic fatty liver disease /NAFLD) to 33 inches (84 cm), average finger glucose reading from 250 mg/dL to 120 mg/dL, and lab-tested A1C from 10% to ~6.5%. One of his major accomplishments is that he no longer takes any diabetes medications since 12/8/2015.

In 2017, he has achieved excellent results on all fronts, especially his glucose control. However, during the pre-COVID period of 2018 and 2019, he traveled to approximately 50+ international cities to attend 65+ medical conferences and made ~120 oral presentations. This hectic schedule inflicted damage to his diabetes control, through dinning out frequently, post-meal exercise disruption, jet lag, and along with the overall metabolism impact due to his irregular life patterns through a busy travel schedule; therefore, his glucose control and overall metabolism state were somewhat affected during this two-year heavier traveling period.

During 2020 with a COVID-19 quarantined lifestyle, not only has he published ~400 medical papers in 100+ journals, but he has also reached his best health conditions for the past 26 years. By the beginning of 2021, his weight was further reduced to 165 lbs. (BMI 24.4) along with a 6.1% A1C value (daily average glucose at 105 mg/dL), without having any medication interventions or insulin injections. These good results are due to his non-traveling, low-stress, and regular daily life routines. Due to his knowledge of chronic diseases, practical lifestyle management experiences, and developed various high-tech tools contribute to his excellent health status since 1/19/2020, which is the start date of being self-quarantined.

On 5/5/2018, he applied a CGM sensor device on his upper arm and checks glucose measurements every 5 minutes for a total of ~288 times each day. He has maintained the same measurement pattern to present day. In his research work, he uses the CGM sensor glucose at time-interval of 15 minutes (96 data per day). By the way, the difference of average sensor glucoses between 5-minute intervals and 15-minute intervals is only 0.4% (average glucose of 114.81 mg/dL for 5-minutes and average glucose of 114.35 mg/dL for 15-minutes with a correlation of 93% between these two sensor glucose curves) during the period from 2/19/20- to 8/13/21.

Therefore, over the past 11 years, he could study and analyze the collected 2+ million data regarding his health status, medical conditions, and lifestyle details. He applies his knowledge, models, and tools from mathematics, physics, engineering, and computer science to conduct his medical research work. His medical research work is based on the aims of achieving both "high precision" with "quantitative proof" in the medical findings.

The following timetable provides a rough sketch of the emphasis of his medical research during each stage:

- 2000-2013: Self-study diabetes and food nutrition, developing a data collection and analysis software.
- 2014: Develop a mathematical model of metabolism, using engineering modeling and advanced mathematics.
- 2015: Weight & FPG prediction models, using neuroscience.
- 2016: PPG & HbA1C prediction models, using optical physics, artificial intelligence (AI), and neuroscience.
- 2017: Complications due to macro-vascular research such as cardiovascular disease (CVD), coronary heart disease (CHD) and stroke, using pattern analysis and segmentation analysis.
- 2018: Complications due to micro-vascular research such as chronic kidney disease (CKD), bladder, foot, and eye issues (DR).
- 2019: CGM big data analysis, using wave theory, energy theory, frequency domain analysis, quantum mechanics, and AI.
- 2020: Cancer, dementia, longevity, geriatrics, DR, hypothyroidism, diabetic foot, diabetic fungal infection, and linkage between metabolism and immunity, learning about certain infectious diseases, such as COVID-19.
- 2021: Applications of linear elastic glucose theory (LEGT) and perturbation theory from quantum mechanics on medical research subjects, such as chronic diseases and their complications, cancer, and dementia. Using metabolism and immunity as the base, he expands his research into cancers, dementia, and COVID-19.

Again, to date, he has collected more than two million data regarding his medical conditions and lifestyle details. In addition, he has written 498 medical papers and published 400+ articles in 100+ various medical journals, including 6 special editions with his 20-25 papers exclusively for each edition. Moreover, he has given ~120 presentations at ~65 international medical conferences. He has continuously dedicated time and effort on medical research work and shared his findings and learnings with other patients worldwide.

ADA TIR% Guidelines

In February 2019, the Advanced Technologies & Treatments for Diabetes (ATTD) Congress assembled an international panel of individuals with diabetes and clinicians and researchers with expertise in CGM. Their objective was to develop clinical CGM targets to supplement the currently agreed-upon metrics for CGM-derived times in three glucose ranges (within TIR, TBR, and TAR) in order to provide guidance for clinicians, researchers, and individuals with diabetes in using, interpreting, and reporting CGM data in routine clinical care and research.

Recently in 2020, the ADA published revised guidelines regarding the CGM collected data which included three newly recommended measurement guidelines: (1) TIR: 70-180 mg/dL for "acceptable" diabetes glucose range; (2) TAR: >180 mg/dL for severe diabetes concerns; and (3) TBR: <70 mg/dL as a warning for insulin shock.

Although the author has already made noticeable improvements on his diabetes control, he wanted to achieve better conditions. Therefore, he established another set of guidelines for his more stringent glucose control by replacing the 180 mg/dL cutoff line with a lower 140 mg/dL for both TIR and TAR. As described above regarding his T2D history, eAG was higher (above 140 mg/dL) prior to 2015 and gradually trended downward around or less than 120 mg/dL after 2017. However, in this particular study, he still adopts the TIR range of 70-180 mg/dL as defined by ADA.

After the ADA's announcement, several research papers have been written regarding this subject. Some minor data differences exist in the studies between References 4 and 5; however, these research papers are based on collected CGM data belonging to diabetes patients. Lacking clear evidence, the author would like to make a logical assumption that "most" of the tested data collected from patients under medications. As we know, medications have a strong and significant effect on suppressing the external symptom of diabetes, but they are not fixing the root causes of the disease. As of 12/8/2015, he has discontinued all of his diabetes medications; therefore, his glucose data are derived directly from his body's biomedical conditions without any external chemical interventions from medications.

Results

Figure 1 shows the ranges of percentages for TIR, TAR, and TBR during 4 sub-periods of 2018, 2019, 2020, and 2021.

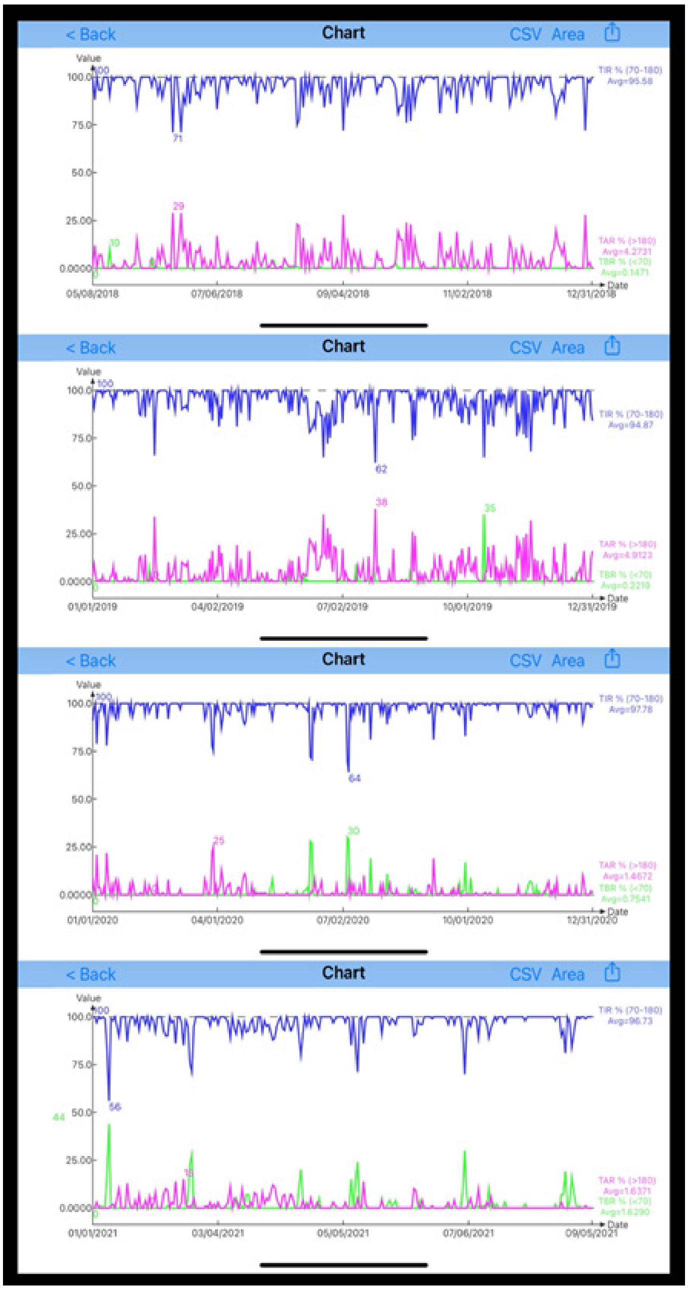
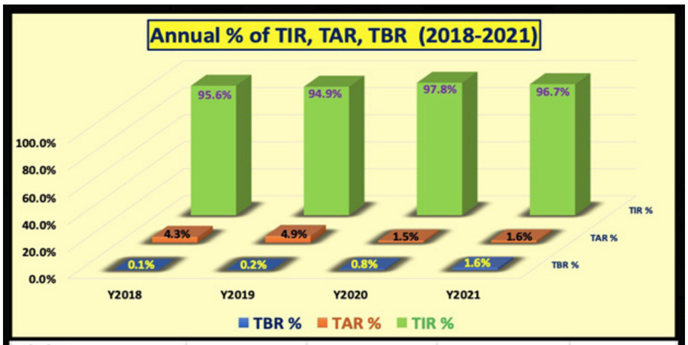


Figure 1: Curves of TIR, TAR, TBR percentages of 4 sub-periods

Figure 2 depicts the range of ***percentages*** for TIR, TAR, and TBR and their associated data table. The following table lists his ***TIR %:***

2018: 95.6%
2019: 94.9%
2020: 97.8%
2019: 96.7%

It should be pointed out that his TIR % during 2020-2021 are higher than 2018-2019 which indicates his T2D control is better during 2020-2021.



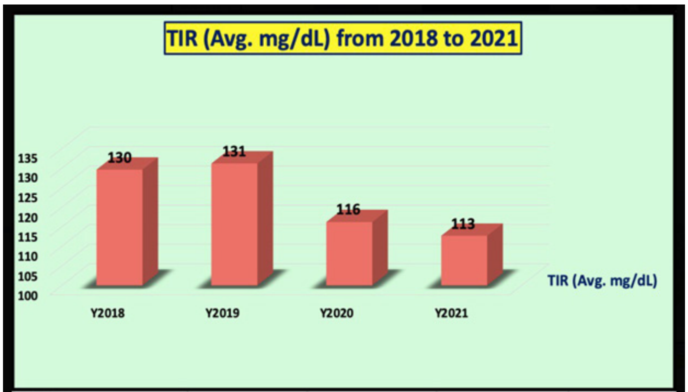
9/6/21				
Gerry	2nd Worst	Worst	Best	2nd Best
Annual (Avg. %)	Y2018	Y2019	Y2020	Y2021
TBR %	0.1%	0.2%	0.8%	1.6%
TAR %	4.3%	4.9%	1.5%	1.6%
TIR %	95.6%	94.9%	97.8%	96.7%
Annual (Avg. mg/dL)	Y2018	Y2019	Y2020	Y2021
TIR (Avg. mg/dL)	130	131	116	113

Figure 2: Bar chart of TIR, TAR, TBR and data table of 4 sub-periods

Figure 3 illustrates his average glucose values for TIR and their associated data table. The following table lists his average glucose values of TIR:

2018: 130 mg/dL
2019: 131 mg/dL
2020: 116 mg/dL
2019: 113 mg/dL

It should be pointed out again that his average glucose for TIR during 2020-2021 are lower than 2018-2019 which means his T2D control in 2020-2021 is better.



9/6/21				
Gerry	2nd Worst	Worst	Best	2nd Best
Annual (Avg. %)	Y2018	Y2019	Y2020	Y2021
TBR %	0.1%	0.2%	0.8%	1.6%
TAR %	4.3%	4.9%	1.5%	1.6%
TIR %	95.6%	94.9%	97.8%	96.7%
Annual (Avg. mg/dL)	Y2018	Y2019	Y2020	Y2021
TIR (Avg. mg/dL)	130	131	116	113

Figure 3: Average glucose values of TIR and data table of 4 sub-periods

Conclusions

In summary, there are three key findings from this study:

1. TIR: Over the past 4 years, his TIR percentages are above 94% and the average TIR values are below 131 mg/dL, along with an average TBR percentages below 1.6% and an averaged TAR percentages below 4.9%. This means that his T2D is well under control with the majority (>94.9%) of glucoses within a reasonable and "acceptable" range. The risks probability of having hypoglycemia are below 1.6%, and his hyperglycemic risk probabilities are below 4.9%.
2. The lower TIR percentages and higher average eAG values over the period of 2018-2019 show that his T2D control is in better condition over the period of 2020-2021 (peaceful and routine lifestyle due to COVID quarantine) than the period of 2018-2019 (heavy travel lifestyle to attend many medical conferences).

This analysis only provides a "macro-view" of his T2D control; however, he needs to identify a "micro-view". Both TIR and HbA1C provide the overview or the mean value of glucose situations. In other words, he needs additional research to gain a better understanding for the "shell of TIR". This will be another topic in future research projects.

References

For editing purposes, majority of the references in this paper, which are self-references, have been removed for this article. Only references from other authors' published sources remain. The bibliography of the author's original self-references can be viewed at www.eclairemd.com.

Readers may use this article as long as the work is properly cited, and their use is educational and not for profit, and the author's original work is not altered.

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