Case Study of a Type 2 Diabetes Patient's Time-In-Range (15-Min) Analysis Using GH-Method: Math-Physical Medicine

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Introduction

The author has applied the American Diabetes Association (ADA) 2020 Guidelines for time-in-range (TIR) % to analyze his type 2 diabetes (T2D) control using his collected personal data. Although he defined a customized TIR range between 70 mg/dL and 140 mg/dL in order to have a more stringent criteria for his diabetes control, it still follows the ADA's concepts.

Method

A continuous glucose monitoring (CGM) sensor device has been placed on his left upper arm to collect 54,598 glucose data over 722 days from 5/5/2018 - 4/26/2020 at a rate of 75.62 glucoses per day. During the same period, he has also collected his finger-piercing glucoses four times each day. Furthermore, his HbA1C has been tested on a quarterly basis.

Recently, the ADA updated its guidelines regarding the CGM collected data [1,2].

The new guidelines include the following three measurement terms:
1. TIR: time-in-range 70-180 mg/dL for "acceptable" diabetes glucose range.
2. TAR: time-above-range >180 mg/dL for severe diabetes concerns.
3. TBR: time-below-range <70 mg/dL for insulin shock warning.

A conversion table between glucose TIR and HbA1C % is shown in Figure 1. After the ADA's announcement, many researchers have written papers about TIR [3-5]. The author also contributed a medical paper regarding the diabetes medication contribution on his HbA1C values using TIR analysis [6].

The most important parameter defined by ADA is the TIR, with a range between 70 mg/dL to 180 mg/dL. However, the author's diabetes history of average daily finger-piercing glucose is highlighted as follows:
1. 280 mg/dL prior to 2010 with three different diabetes medications.
2. 135 mg/dL in 2014 when he developed a mathematical model of metabolism and then reduced his body weight by 25 lbs. via a stringent lifestyle management program.
3. 129 mg/dL in 2016 after he stopped taking diabetes medications.
4. 118 mg/dL from January through May of 2018 before he collected his CGM glucose data.
5. 114 mg/dL during the period of 5/5/2018 - 4/26/2020 with CGM and no medication.

Based on the above observations, he decided to define a "customized" TIR range between 70 mg/dL to 140 mg/dL to study his own data and situations.

Results

Figure 2 shows his results of TIR (70-180), TAR, and TBR using the ADA definition, with a TIR of 96% and average of 127 mg/dL. Figure 3 illustrates his results of TIR (70-140), TAR, and TBR using his customized definition with a TIR of 71% and average of 118 mg/dL. The ADA definition results in an extremely high % of TIR (96%), while his customized definition results in a lower % of TIR (71%). However, this 71% of TIR matches with the corresponding HbA1C of 6.7% using the conversion table which happens to be his actual lab-tested average HbA1C during this time period (see Figure 4). If applying ADA related conversion table using TIR value of 96%, his HbA1C would then be as low as 4.8%, which he believes is too low for a T2D patient like himself. That is why he defines his own TIR definition and a range to fit with his collected CGM data and reflect his actual diabetes situation.

Figure 5, 6, and 7 depict percentages and average glucose value (mg/dL) for both ADA definition and customized definition.

Time-in-range	HbA1c (%)
0%	12.1
10%	11.4
20%	10.6
30%	9.8
40%	9.0
50%	8.3
60%	7.5
70%	6.7
80%	5.9
90%	5.1
100%	4.3

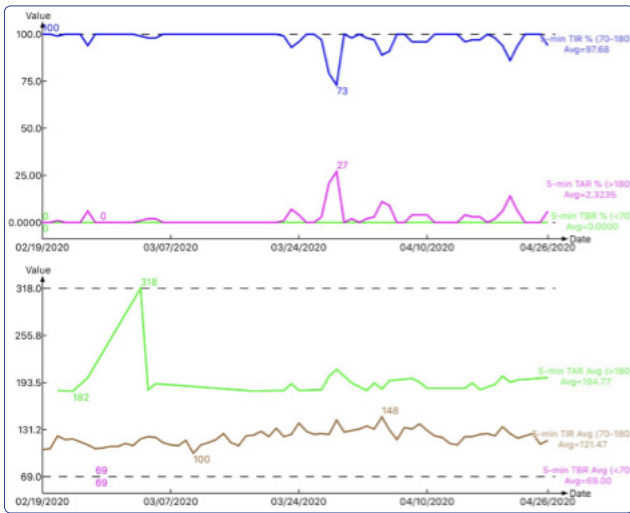**Figure 1:** ADA-based conversion table between TIR % and HbA1C

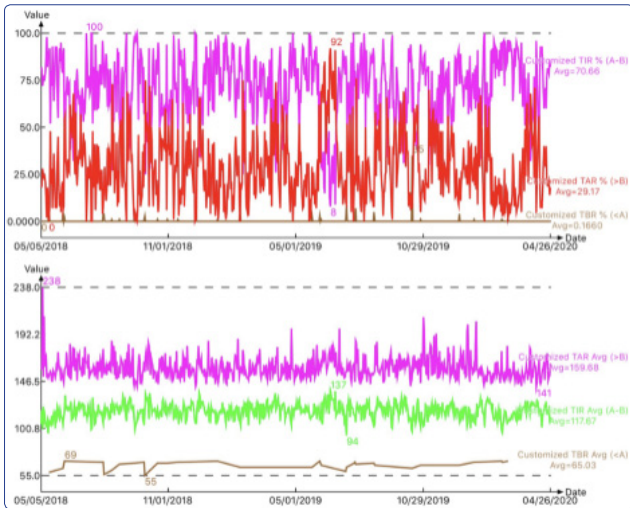**Figure 2:** Percentages and average glucose values of TIR, TAR, and TBR for ADA definition

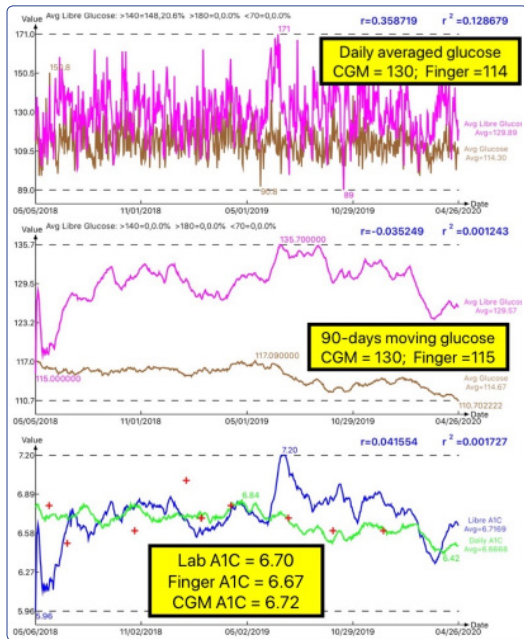**Figure 3:** Percentages and average glucose values of TIR, TAR, and TBR for Customized definition

Figure 4: Daily average glucoses, 90-days moving average glucoses, and HbA1C (Finger, CGM, & Lab)

ADA	ADA %		ADA mg/dL
TIR (70-180)	95.5%	TIR (70-180)	127
TAR (>180)	4.4%	TAR (>180)	196
TBR (<70)	0.2%	TBR (<70)	65
Customized	GH %		GH mg/dL
TIR (70-140)	70.7%	TIR (70-180)	118
TAR (>140)	29.2%	TAR (>180)	160
TBR (<70)	0.2%	TBR (<70)	65

Figure 5: Percentages and Average glucoses of TIR, TBR, and TAR for both ADA definition and Customized definition
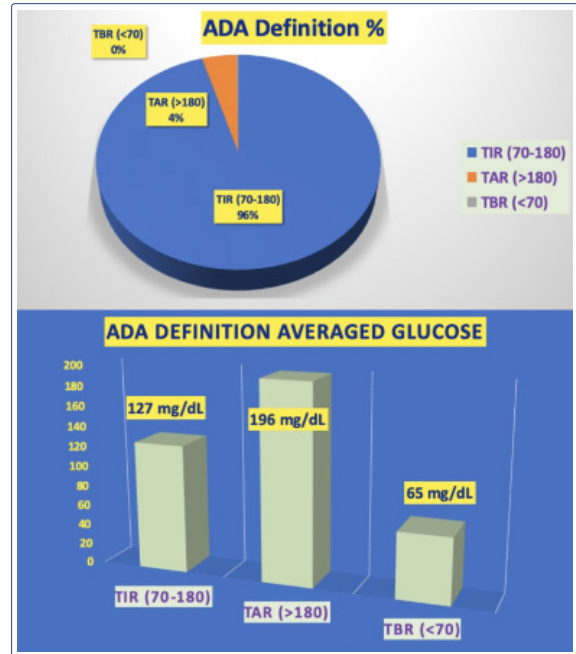

Figure 6: Percentages (pie chart) and Average glucoses (bar chart) of TIR, TBR, TAR for ADA definition
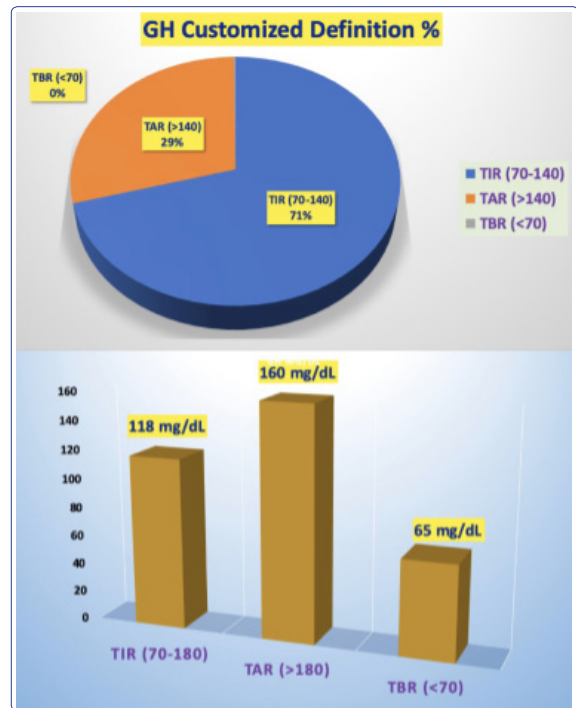

Figure 7: Percentages (pie chart) and Average glucoses (bar chart) of TIR, TBR, and TAR for Customized definition

With this tighter and more stringent range of customized TIR, it would be easier for him to observe his own diabetes situation change and control improvement of his diabetes with "precision". He will not be overly satisfied with this extremely high TIR of 96% and relax his own diabetes control program.

Conclusions

This research paper demonstrates that the CGM glucose data provides an overall detailed comprehensive picture of a diabetes patient's glucose profile. However, after reviewing his own case with ~54,600 data, the author decided to define a tighter range of TIR between 70 mg/dL to 140 mg/dL (beginning level of diabetes), instead of using the ADA's 70 mg/dL to 180 mg/dL. With this tighter customized TIR range, he could derive a TIR percentage which is closer to his lab-tested average HbA1C value. By checking his past history of glucose conditions over the past 10-years, his customized definition seems to be a better fit with his own situation. This may be a result from the ADA's recommendation based on patients under medications, while the author's data is totally medication free. Therefore, whether his approach is suitable for other patients or not, he will need more analyses to verify it.

References

1. American Diabetes Association (2020) Diabetes Care 43: s1-s212.
2. Tadej Battelino, Thomas Danne, Moshe Phillip (2019) 2-LB: CGM-Based Clinical Targets: Recommendations from the International Consensus on Time-in-Range (TIR). Diabetes 68.
3. Vigersky R, McMahon C (2019) Diabetes Technol Ther 21: 81-85.
4. Beck RW, Bergenstal RM, Cheng P, Craig Kollman, Anders L Carlson, et al. (2019) The Relationships Between Time in Range, Hyperglycemia Metrics, and HbA1c. J Diabetes Sci Technol 13: 614-626.
5. Battelino T, Danne T, Bergenstal RM, Stephanie A. Amiel, Roy Beck, et al. (2019) Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations From the International Consensus on Time in Range. Diabetes Care 42: 1593-1603.