Q-Score complements the TIR in the evaluation of short-term glycemic control

Petra Augstein[1], Peter Heinke[2], Alexandra Nowak[1], Jörg Reindel[1], Eckhard Salzsieder[2], Wolfgang Kerner[1]

[1]Klinikum Karlsburg, Herz- und Diabeteszentrum, [2]Institut für Diabetes "Gerhardt Katsch", Karlsburg

Augstein, P., Heinke, P., Vogt, L. et al. Q-Score: development of a new metric for continuous glucose monitoring that enables stratification of antihyperglycaemic therapies. *BMC Endocr Disord* **15**, 22 (2015).

Background

The Q-Score[1] is a single-number composite metric of the quality of daily glucose profiles with a recording period of at least 3 days. It is calculated from five parameters:

- Mean sensor glucose
- Variability Max – Min in a day
- Time in hyperglycemia
- Time in hypoglycemia
- Variability from day to day

Aims

Herein, we refined the Q-Score for the screening and analysis of short-term glycemic control.

Material and Methods

Part 1: Adjustment of the Q-Score to the target range 3.9 – 10 mmol/L

- Historical data; n=1562 CGM profiles, 499 women and 1063 men with type 1 (n = 48) and type 2 diabetes (n = 1514)
- Adjustment of the hyperglycemia limit "time above target range" (TAR) from 8.9 to 10 mmol/L
- Correlation analysis and adjustment of the formula for calculating the Q-score for the target range for euglycemia 3.9 - 10 mmol/l

Part 2: Observational study

Outpatient care
People with diabetes (PwD) using intermittent glucose scanning (isCGM) under everyday conditions

Inpatient care
275 PwD admitted for ipatient diabetes care
PwD using isCGM
Diabetes laboratory

Inclusion criteria for the observational study

- People with diabetes mellitus: type 1, type 2 and pancreatic
- Glucose self-monitoring with the Freestyle Libre 2 System (isCGM)
- Sensor data quality > 70%
- CGM recording time at least 14 days

Abbreviations
CGM = Continous glucose monitoring
GRI = Glycemia Risk Index
GMI = Glucose Management Index
isCGM = Intermittently scanned Continuous Glucose Monitoring with the Freestyle Libre 2 system
MSG = Mean sensor glukose
MODD = Mean Of Daily Differences[3]
TIR, TAR, TBR = Times in, above and below the target range of 3.9–10.0 mmol/L

Data analysis:

Determing time to stability

- for Q-Score, TIR, CV and Q-Score parameters using the correlation-based method derived from incremental sampling durations[2] between 1 und 21 recording days
- Stability is achieved at a minimum data duration that exceeds a coefficient of determination of 0.95
- Data derived from n= 254 isCGM profiles

Correlation analyzes with Spearman's correlation coefficient

Q-Score to assess glycemic control

Identification of Q-Score parameters to optimize metabolic control

Statistical methods

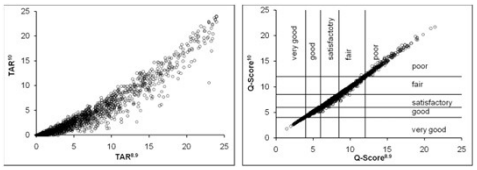
- Differences between study groups: 1-way ANOVA
- Changes in parameters: t-test

A p=0.05 was used as the significance threshold.

Results

Part 1:
Adjustment of the Q-Score to the target range 3.9 – 10 mmol/L

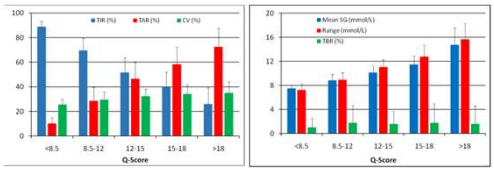
Fig. 1
Scatter plot showing the relationship of the Q-Score parameter $TAR^{8.9}$ vs. adjusted TAR^{10} (A) and the Q-Score calculated with $TAR^{8.9}$ vs. TAR^{10} (B). Assessment Q-Score: < 4 very good, 4-6 good, 6-8.5 satisfactory, 8.5-12 still sufficient, >12 inadequate.
Abbreviations: $TAR^{8.9}$ = Time above target range 8.9 mmol/L; TAR^{10} = TAR above 10 mmol/L.



- Correlation $TAR^{8.9}$ vs. adjusted TAR^{10} (r = 0.958)
- The Q-Score formula was adjusted to TIR 3.9 – 10 mmol/L:
  Q-Score = 8 + (MSG-7.8)/1.7 + (Range-7.5)/2.9 + (TBR-0.6)/1.2 + **$(TAR^{10}$-3.9)/4.8** + (MODD-1.8)/0.9
- The linear function between the Q-Scores using both TAR was:
  $Q\text{-Score}^{10}$ = -0.03 + 1.00 $Q\text{-Score}^{8.9}$
- Correlation $Q\text{-Score}^{8.9}$ vs. adjusted^{10} (r=0.997)
- Classification using both Q-Score formulas resulted in a high concordance of 92.6 % for tested1562 CGM profiles.

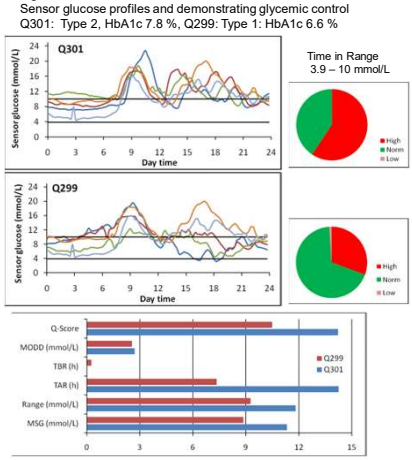
Q-Score to assess metabolic control

Fig. 4
Q-Score components depending on glycemic quality determined by Q-Score. Data in Mean+SD.



- Q-Score categories for inadequate glycemic control have significantly reduced TIR, increased TAR, CV and MSG
- With a deterioration in metabolic control TIR decreases and the TAR, CV and MSG increase significantly (ANOVA test).

Fig. 4
Sensor glucose profiles and demonstrating glycemic control
Q301: Type 2, HbA1c 7.8 %, Q299: Type 1: HbA1c 6.6 %



Part 2:
Observational study

Table 1
Subject characteristics of the observational study

	Type of diabetes			
Parameter	Type 1	Type 2	Pancreatic	All
N	142	116	17	275
Sex (female/male)	66/76	57/59	4/13	127/148
Age (years)	53.9 ± 15.,8	65.0 ± 9.0	57.7 ± 8.0	58.8 ± 14.0
Duration of diabetes (years)	25.5 ± 18.1	20.6 ± 11.8	11.8 ± 11.4	22.5 ± 15.7
BMI (kg/m²)	27.6 ± 5.3	35.0 ± 10.8	27.1 ± 5.3	30.7 ± 8.9
Therapy (OAD/OAD+Insulin/Insulin)	0/4/138	10/77/29	0/1/16	10/82/183
HbA1c (%)	8.17 ± 1.29	8.17 ± 1.22	8.04 ± 1.38	8.16 ± 1.26
TIR (%)(%)	52 ± 20	57 ± 26	58 ± 20	54 ± 23
Q-Score	15.2 ± 3.0	11.8 ± 4.4	13.5 ± 4.8	13.7 ± 4.6
Subjects with TIR>70% (%)	21.1	35.3	29.4	27.6
Subjects with acceptable metabolic control in Q-Score (%)	5.7	22.7	25.0	13.8

Correlation analyses

Fig. 3
Scatter plot for Q-Score vs.TIR (isCGM profile), data are from people with type 1, type 2 und pancreatic diabetes mellitus.

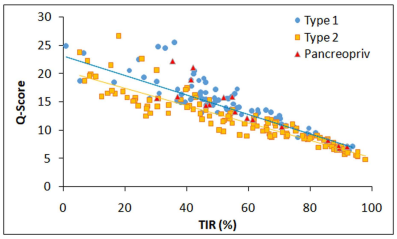


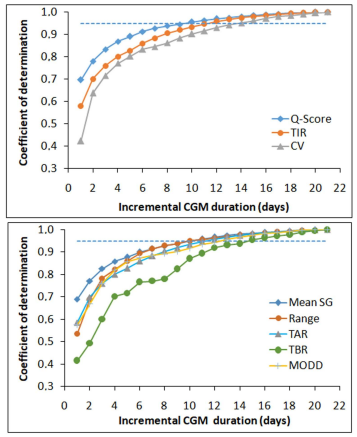
Table 2
Correlations of the Q-Score with other metabolic control parameters

Metabolic parameter	Type 1	Type 2	all	Significance of the increases
Fructosamine (µmol/L)	0.653	0.684	0.698	
TIR (%)	-0.896	-0,915	-0.874	<0.05
GMI (%)	0.901	0.941	0.877	
GRI (%)	0.943	0.948	0.928	
HbA1c (%)	0.795	0.807	0.742	

- The correlations of the Q-Score with TIR, GMI and fructosamine are not significantly different between both types of diabetes.
- Only ithe slopes of the regression lines of the relationship between the TIR and the Q-score are significantly different for both types of diabetes. This means that as the TIR worsens, the differences in the Q-score between the types of diabetes become larger.
- The Q-Sore correlates highest with the GRI due to the assessment of the CGM curves by experts.

Determing time to stability

Fig. 2
Time to stability for Q-Score, TIR and CV (A) and for the Q-Score components (B). N=254



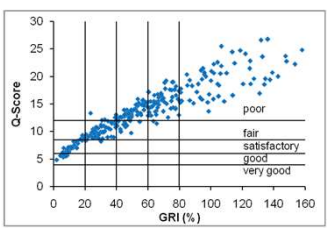
- The Q-Score was stable after 13 days of CGM, TIR after 12 and CV after 14 days.
- The parameters Mean, SG, Range, TAR and MODD were stable after 11 to 13 days, TBR only after 16 days.

Identification of the parameters for optimization of metabolic control

Table 3
Q-Score and its components in relation to parameters of glycemic control determined using the respective regressions.

Q-Score	TIR (%)	HbA1c (%)	GRI	Mean SG (mmol/L)	Range (mmol/L)	TAR (%)	MODD (mmol/L)
6	87.3	6.6	3.9	6.5	6.4	11.2	1.4
8.5	76.5	7.1	21.3	7.8	8.0	22.0	2.0
10	**70.1**	**7.4**	**31.8**	**8.6**	**8.9**	**28.4**	**2.4**
12	61.4	7.8	45.8	9.6	10.1	37.0	2.8
15	48.5	8.4	66.8	11.2	12.0	49.9	3.5
18	35.5	9.0	87.8	12.8	13.8	62.8	4.3

Fig. 6
Scatterplot for Q-Score with GRI (n= 261 isCGM profiles)



- The Q-Score correlates with the GRI (r=0.928).
- A GRI<20 corresponds to a satisfactory Q-Score, a GRI<40 to an adequate Q-Score

Summary

The Q-Score was adjusted to the target range of 3.9 – 10 mmol/L and a high correlation between Q-Score 8.9 and Q-Score 10 was demonstrated. The Q-Score is stable after 13 days of CGM recording. The Q-Score is highly correlated with parameters of short-term metabolic control such as TIR, fructosamine and GMI. Q-Score is suitable for assessing short-term metabolic control and allows the identification of individual parameters that can be improved.

Referenzen
[1] Augstein, P., Heinke, P., Vogt, L. *et al. BMC Endocr Disord* **15**, 22 (2015)
[2] Rama Chandran et al, Diabetes Technol Ther 2020;22:937-942
[3] Molnar GD et al, Diabetologia 8 (1972), 342-348