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Research Article

Improving Diabetes Care Through Teamwork, Comprehensive Education, Tighter Goals, and Technology: Single-Center Data from Türkiye

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What is already known on this topic

- Achieving better glycaemic control while maintaining a quality of life similar to that of peers is a challenging issue in the management of type 1 diabetes.
- Use of diabetes technologies helps to achieve better metabolic control in type 1 diabetes.

What this study adds

- Holistic approaches that focus on patient behaviors, comprehensive education, teamwork, written individualized treatment plans, and tighter metabolic targets are effective in achieving better glycemic outcomes.
- Most of the glycemic metrics of automated insulin delivery (AID) users were significantly better compared to MDI and CGM users and non-AID pump users.

Abstract

Introduction: The management of type 1 diabetes (T1D) in children aims to achieve an HbA1c of <7%, a good quality of life and a life similar to that of their peers. While the HbA1c <7% target may be difficult to achieve, it is possible that national programs, quality control programs and setting team targets can achieve significant reductions in HbA1c.

Methods: The records of children with T1D followed up in our department between 2020 and 2022 were analyzed. Children and their families received a comprehensive education including an 'Individual Treatment Plan', nutrition and carbohydrate counting. All HbA1c measured during follow-up were averaged for each child separately. Continuous glucose monitoring (CGM) data from the last visit was evaluated in terms of achieving CGM consensus targets. To assess the effect of CGM use and automated insulin delivery system (AID) use, subjects were divided into 3 groups as multiple dose insulin (MDI) and CGM users, non-AID pump users and AID users and evaluated.

Results: The 480 children included in the study had a mean HbA1c of 7.8±1.5% at the first visit. The median HbA1c value during the two-year follow-up was 7.1%. Of the participants, 43% had an HbA1c <7%. Evaluating cases by treatment modalities and glucose measurement methods revealed taht AID users having the lowest mean HbA1c (7±0.7%).

Conclusions: While diabetes technologies have significantly improved T1D treatment, we believe that holistic approaches focusing on patient behaviors, comprehensive education, teamwork, written individualized treatment plans, and tighter metabolic goals are effective in achieving better glycemic outcomes.

Keywords: Carbohydrate counting, diabetes technologies, individual treatment plan, Type 1 Diabetes

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Introduction

The management of type 1 diabetes (T1D) in childhood requires a holistic approach that encompasses not only glycemic outcomes but also quality of life and the ability of children and their families to lead daily lives similar to those of their peers (1). Current targets for glycemic outcomes reflect the need to minimize hyperglycemia as safely as possible and include an HbA1c target of <7% (HbA1c target is <6.5% in stage 3 T1D and remission periods, in those with access to advanced technology, and in those followed up in clinics providing advanced education/services), coefficient of variation (CV) of <36%, a glucose value in the range of 70-180 mg/dl (Time In Range-TIR) >70%, and a fasting glucose target of 70-144 mg/dl (2).

Despite targets being increasingly tightened over the years, the management of T1D in children remains a challenging issue, with mean/median HbA1c levels of 7.5% and above in almost all countries across the globe (3). In a recent study made up of 8004 children younger than 6 years old with T1D from the USA, Europe and Australia, it was highlighted that more than half of the children were not able to achieve the target HbA1c value of <7.0% despite the high rate of continuous glucose monitoring (CGM) use (4). In contrast, centers in countries such as Slovenia, Australia, Norway and Sweden have achieved significant reductions in HbA1c levels within a period of 10-12 years (ranging from 9.26% to 7.75% in Slovenia, 8.2% to 7.2% in Norway, and an average of 6.7-6.8% in Sweden and Australia) due to nationwide practices, quality control programs, team goal setting and benchmarking (5-8). Promisingly, the 4T project in the USA has clearly demonstrated the multifaceted positive effects of structured programs involving teamwork, goals, technology and tight controls in diabetes management, especially HbA1c (9, 10).

Since there is no national registration system in Türkiye, metabolic control data is limited. In a study published in 2013 involving 1032 cases from various centers at the national level, the mean HbA1c was found to be 8.5%, and in another study involving 498 cases at the national level

and published in 2016, this figure was 8.6% (11,12). In a recent cohort study of the data of 2730 children from 42 centers between 2018 and 2023, the median HbA1c was reported as 8.4% (13). This data shows that the average HbA1c in Türkiye is higher than the intended target and that there has been no improvement in the last 10 years.

This study aims to present the results of our program, the main components of which are teamwork, comprehensive training, tightening of targets and use of technology, as a basis for a national diabetes program.

Method

The records of children with T1D who were followed up in the Department of Pediatric Endocrinology and Diabetes at Koç University Hospital between June 2020 and June 2022 were collected retrospectively. These children and their families received comprehensive training including education on nutrition, and practice in carbohydrate counting. During the comprehensive training, children and their families are first informed about what T1D is, general lifestyle recommendations (doing sports, not consuming junk food, daily life order, etc.), diabetes management during fasting, diabetes management during postprandial, additional dose application strategies, international targets such as HbA1c in diabetes and how long time in the target range should be, '10 Basic Recommendations' are explained (14, 15). Then, an individualized treatment plan according to the weight of the child is given to the family in writing. Afterwards, during the interview with the diabetes education nurse, which lasts for 1-2 hours, how to measure blood glucose, insulin injection application, injection sites and the importance of rotation, hyperglycemia management, hypoglycemia management, glucagon application, ketone monitoring, management of sick days, CGM and pump types available in Türkiye are explained. During the dietitian meeting, which lasts three sessions, each lasting one hour, carbohydrate counting is explained first. In the second meeting, sample menus are prepared by giving individualized insulin-carbohydrate ratios to the child and family who come with a food consumption form. In the final meeting, the effects of protein and fat on blood glucose, and exercise management are explained. In the psychologist interview, acceptance of T1D, how diabetes can be explained to young children, depression scale are done. Motivational interviewing sessions are provided to support families and children coping with diabetes-related burnout. The frequency of psychologist meetings is determined according to individual needs. The doctor's interview is repeated every 3 months and their education is reviewed by the diabetes education nurse during each visit. The dietitian visit is repeated every 6 months.

The inclusion criteria for the study were having T1D for at least 1 year, attending at least 2 outpatient clinic visits and having a follow-up period of at least 6 months. Insulin dose adjusted HbA1c (IDAA1c) value was calculated and if ≤9%, the cases were considered to be in the honeymoon period and excluded from the study. The formula HbA1c (percent) + [4 x insulin dose (units per kilogram per 24 h)] was used to calculate this value (Figure 1) (16). Children's age, gender, duration of diabetes, blood glucose measurement methods (self-monitoring of blood glucose [SMBG], Flash-CGM [f-CGM], real-time CGM [rt-CGM]), treatment modalities (multiple-dose insulin [MDI], automated insulin delivery [AID], non-AID insulin pump), and total daily insulin doses (TDI) were collected from electronic health records. Automated insulin delivery pump used in this study was AHCL (Advanced Hybrid Closed Loop), and non-AID pumps were sensor augmented Minimed 640G and Medtronic Paradigm Veo 754, and the patch pump Omnipod DASH. All HbA1c measurements were collected over a 2-year study period where the mean HbA1c was calculated for individuals and grouped as follows: <6.5%, 6.6-7%, 7.1-8%, 8.1-9% and >9%. The last 14 days of CGM data for the last visit were evaluated in terms of achieving the International CGM consensus targets (TIR [70-180mg/dl], TAR1 [180-250mg/dl], TAR2 [>250mg/dl], TBR1 [54-70mg/dl], TBR2 [<54mg/dl], mean sensor glucose [Mean SG], CV, glucose management indicator [GMI] parameters) and TIR >70% and CV <36% (14).

HbA1c and CGM metrics were compared between pump users and MDI users. In order to evaluate the effect of CGM use and AID use on metabolic control separately, the subjects were divided into 3 groups - those who used MDI and CGM, those who used non-AID pump and those who used AID - and were evaluated in terms of the same parameters. In a separate analysis, the metabolic parameters of 203 children using CGM were compared according to the type of sensor they used, f-CGM (Abbott Freestyle Libre) and rt-CGM (Dexcom G6, Medtronic Guardian Connect), and evaluated in terms of achieving international CGM use consensus targets (14).

In addition cases were grouped according to the duration of diabetes technology (CGM/pump) use as those who had used it for ≤2 years and those who had used it for >2 years, and the effect of increasing duration of diabetes technology use on glycemic control was evaluated.

Statistical Analysis

All analyses were conducted using SPSS version 26 (IBM SPSS Statistics for Windows, Version 26.0. IBM Corp, Armonk, NY, USA). The Kolmogorov Smirnov test was performed to determine whether the variables were normally distributed. Mean ± standard deviation (SD) values were used to define normally distributed continuous variables, and median and interquartile ranges (IQR) were used to define non-normally distributed continuous variables. Frequency and percentage terms were used to describe categorical variables. In paired group comparisons, Student T test was used for independent continuous variables with normal distribution and p value was determined according to Levene's analysis of variance and the Mann-Whitney U test was used for non-normally distributed independent continuous variables. In comparisons of more than two normally distributed independent groups, if the sample difference between the groups was large, variance analysis was performed with the Levene test. One-Way ANOVA test was performed if there was equality of variance, otherwise Welch-ANOVA test was performed. The groups between which the difference occurred were evaluated with Games Howell post hoc analysis. The Kruskall-Wallis test was used for comparisons of more than two non-normally distributed groups, and the groups between which the difference occurred were evaluated using the Mann-Whitney U test and Bonferroni correction. The chi-square test was used for comparing categorical variables. A value of $P < 0.05$ was considered statistically significant. The protocols were conducted according to the Declaration of Helsinki principles and were approved by the Institutional Research Ethics Committee (2025.139.IRB3.060).

Results

Of the 480 children included in the study, 50% were male, the mean age was 11.4±4.2 years, the mean age at diagnosis of diabetes was 6.9±3.9 years, and the cases presented to our clinic for the first time had a median of 0.4 years (0.06 – 2.4) after the diagnosis of diabetes. The mean number of visits was 4.2±1.7 and they were followed up for a mean of 2.7±1.4 years.

Demographic and metabolic parameters at the baseline are given in Table 1, 72% (344) were using MDI and 28% (136) were using AID or non-AID pump. Of the MDI users, 40% had SMBG, 41% with f-CGM, 19% rt-CGM (17% with Dexcom G6, and 2% with Guardian Connect). Of the pump users, 43% were using AID (AHCL) 57% were using a non-AID pump (32% Minimed 640G, 15% Medtronic Veo 754, and 9% Omnipod DASH).

The mean TDI of the whole group was 0.8±0.2U/kg/day. The mean HbA1c level was 7.8±1.5% at baseline, the mean number of HbA1c measurements during follow-up was 3.1±1.5, and the mean and median HbA1c values were 7.3±1.1% and 7.1%, respectively. Of the measured HbA1c values, 21% were <6.5%, 22% between 6.6-7%, 37% between 7.1-8%, 13% between 8.1-9%, and 7% >9%. In the CGM users, the mean TIR was 66.2±13.8%, TAR 1 (180-250mg/dl) 20.2±9.3%, mean SG 149.5±23mg/dl, CV 39±7%, GMI 6.8±0.5%, median TAR 2 (>250mg/dl) 6%, TBR 1 (54-70mg/dl) 4%, and TBR 2 (>54mg/dl) 1%.

When the cases were divided into 3 groups according to treatment modalities and glucose measurement methods, those who were on MDI and CGM (n:203), those who used a non-AID pump (n:77) and those who used AID (n:59), the lowest mean HbA1c value in AID users (7±0.7 %),

although there was no statistically significant difference (p: 0.060). The ratio of there being a HbA1c <7% was highest in AID users with 58%. Of those using AID, 88% achieved the TIR >70% target. All of the glycemic metrics of AID users were significantly better compared to other treatment modalities and glucose monitoring methods, the TIR values of MDI users with CGM and non-AID pump users were 62.4±12.6% and 66.3±13.5%, and the TIR of AID users was 79.6±8.5% and significantly higher (p: <0.001). The mean TAR 1 (180-250mg/dl) values of MDI users with CGM was 21.1±8.4%, in non-AID pump users this was 24.2±11.2%, in AID users this was 13.7±6.5%, and was significantly lower in AID users compared to the other two groups (p: <0.001). The median TAR 2 (>250mg/dl) was 2% in AID users, 6% in non-AID pump users, and 8% in those using MDI with CGM, and was significantly lower in AID users compared to the other two groups (p: <0.001). The respective median TBR 1 (54-70mg/dl) and TBR2 (<54mg/dl) were 2% and 0% in AID users, 2% and 1% in non-AID pump users and 5% and 1% in MDI users with CGM glucose monitoring, and it was significantly higher in MDI users with CGM than the other two groups (p1: <0.001, p2: <0.001) (Figure 2). The mean SG was 135.2±14.1mg/dl in AID users, 155.3±22.1mg/dl in non-AID pump users and 152.2±23.9mg/dl in MDI users with AID, and was significantly lower in AID users compared to the other two groups (p: <0.001). The mean CV was 33.7±5.1% in AID users, 37.4±5.4% in non-AID pump users, 41.5±6.9% in MDI users and there was statistically significant difference between them (p: <0.001). The ratio of individuals with a CV <36% was significantly higher among AID users compared to non-AID pump users and MDI users with CGM (66%, 34%, and 21%, respectively; p < 0.001). Mean GMI was also significantly lower in AID users compared with non-AID pump users and MDI users with CGM glucose monitoring (6.5±0.3% vs 7±0.5% vs 6.9±0.6%, p: <0.001) (Table 2).

When the glycemic outcome was evaluated regarding insulin treatment modality, the mean HbA1c was 7.2±0.9% in pump users and 7.4±1.2% in MDI users, with a statistically significant difference (p: 0. 048); according to glucose monitoring method in MDI users, the mean HbA1c was 7.8±1.4% in those who performed SMBG and 7±0.8% in those who used CGM and there was a statistically significant difference between them (p: <0.001).

When the glycemic parameters of individuals using MDI and CGM were compared in terms of the type of CGM used, i.e. f-CGM (FreeStyle Libre, n:140) and rt-CGM (Dexcom G6, [n:58] and Guardian Connect [n:5], n:63), it was observed that the use of rt-CGM provided better glycemic outcomes. The mean HbA1c of rt-CGM users was 6.7±0.7%, while the mean HbA1c of f-CGM users was 7.2±0.8% and there was a statistically significant difference between them (p:<0.001). The mean TIR was 68.1±12.4% in rt-CGM users and 59.2±11.7% in f-CGM users and was significantly higher in rt-CGM users (p<0.001). Mean TAR 1 (180-250mg/dl) was significantly lower in rt-CGM users compared to f-CGM users (19.4±7.8 vs 21.8±8.6, p: 0.038). Median TBR 1 (54-70mg/dl) and TBR 2 (<54mg/dl) values were significantly lower in rt-CGM users than in f-CGM users (4% vs 5%, p1: <0.001; 1% vs 2% p2: 0.004, respectively). The CV value was 38.6±5.5% in rt-CGM users and 42.6±7% in f-CGM users, and CV was significantly lower in rt-CGM users (p:0.001). The rate of individuals with a TIR >70% was significantly higher in rt-CGM users compared to f-CGM users (46% vs 21%, p: 0.001) (Table 3).

When evaluated according to the duration of diabetes technology use, the mean HbA1c level was 6.9 ± 0.8% in those with ≤2 years of technology use and 7.3 ± 0.9% in those with >2 years, and it was significantly lower in those with ≤2 years of technology use (p < 0.001). The mean TIR value was significantly higher in those with ≤2 years of technology use (68.2 ± 13.8%) compared to those with >2 years (64.6 ± 13.6%) (p: 0.026). There was no statistically significant difference between them in terms of TBR1 and TBR2 values (p1: 0.671, p2: 0.312) (Tablo 4).

Discussion

In this single center study examining the glycemic outcomes of children with T1D, 480 children with regular follow-up between 2020 and 2022 had a median HbA1c of 7.1%, where 43% of cases had a HbA1c <7%, and only 7% had a HbA1c above 9%. These values are significantly lower than the previously reported mean HbA1c levels from Türkiye (8.5%, 8.6% and 8.4%) and it is noteworthy that the rate of HbA1c >9% is much more significantly lower (the rate of HbA1c>9% in these studies was 36.9% and 35.7%, respectively) (11-13).

Our data shows that the best metabolic results, especially TIR and HbA1c, were obtained in the group using an AID. The T1D cases followed in our department use AHCL as AID and in this group, the mean HbA1c was 7% and the mean TIR was 79.6%, providing better glycemic results than all groups using sensors. As it is known, the most important contribution of AID to diabetes management is that it provides adaptive basal insulin according to the basal insulin requirement that varies according to many factors during the day, as well as making small adjustments every five minutes instead of making large adjustments at infrequent intervals (17). Recently published studies have shown that these systems, when set optimally, can achieve targets not only for TIR but also for TITR, regardless of country (18,19). Our data also supports that, in the long term, all children with T1D should use AID, which is the most physiological method of insulin delivery.

The use of CGM leads to better glycemic parameters compared to SMBG (20). In our case group, the mean HbA1c of those with SMBG was 7.8±1.4%, while the mean HbA1c of those using CGM was 7.1±0.9%. When an evaluation was made between CGMs, HbA1c was 6.7±0.7% and TIR was 68.1±12.4% in rt-CGM use, while HbA1c was 7.2±0.8% and TIR was 59.2±11.7% in f-CGM use. In the CORRIDA study evaluating the effect of f-CGM and rt-CGM on metabolic parameters, similar to our data, rt-CGM improved metabolic parameters better (21). This suggests that it was sensor use that made a difference on glycemic parameters after AID use.

However, as the duration of diabetes increases, glycemic parameters may worsen in individuals with T1D due to loss of motivation and burnout, and the solution to this situation also requires a multidisciplinary team approach (22). In our study, it is seen that metabolic control of the cases is affected as the duration of diabetes increases, but follow-up of these cases is ongoing and long-term results may become better with a multidisciplinary team approach.

The pediatric diabetes program in our department was started in 2016 with the establishment of a new center and so far around 2000 children with T1D have been seen. Our department has a pediatric diabetes team consisting of 2 physicians, 1 fellow, 2 nurse, 1 dietician and 1 psychologist. Each case is allocated an hour of time by the physicians in the first interview and topics such as individual treatment recommendations, glucose targets, insulin dose calculations (insulin/carbohydrate ratios and correction factor according to meals), rules to be followed before going to bed at night, reverse dawn phenomenon and management, hypoglycemia management, timing and calculating correction doses, optimal carbohydrate amount, 'diabetes team at home' and the role of fathers are emphasized. All recommendations are made for each child according to the age and characteristics of the child and given to the family in writing as an "Individual Treatment Plan". In addition, a basic diabetes education update is provided at the first visit and nutrition/carbohydrate counting training is provided at a separate appointment for each case.

In addition to the relatively better conditions of the cases admitted to our department, we think that the comprehensive education, teamwork, "10 Basic Recommendations" that set the basic goals and the use of technology are effective in achieving these glycemic results in our department (15). In Türkiye, sensors were not reimbursed at the time of this study was conducted and there is limited support for insulin pump therapy. However, the rate of self-provided sensor uses in the cases followed up in our department is higher than the national average, and our data show that sensor use leads to higher HbA1c achievement in cases on MDI therapy. Previously published studies from Sweden and the Czech Republic, and more recently from the USA and Norway, show that equal access to CGM immediately after diagnosis of T1D can be a first step towards improving HbA1c for all young people (3, 8, 23,24). Our data and the aforementioned studies show that the most important step to be taken in changing the lives of around 30,000 children with T1D in Türkiye and to ensure that they live normal and healthy lives like their peers is to provide unconditional CGM support to all children with T1D, regardless of income, through the social security system and global reimbursement.

Today, the fact that glycemic outcomes are not achieving the recommended targets is largely due to glucose fluctuations during daylight hours and the attitudes of people with T1D and/or their families. In most cases, attitudes such as the impracticality of treatment recommendations, unclear communication on glycemic targets, and incompatibility between the goals of diabetes teams and families are common. Additional issues include the habit of eating three main meals and three snacks, which was recommended when regular insulin was used, variations in education on nutrition (25), not administering or delaying the correction dose, going to bed with high glucose levels due to fear of hypoglycemia (26), and neglecting carbohydrate counting and meal composition. Failure to achieve recommended targets leads to a loss of motivation and inertia characterized by a gradual move away from long-term goals (27). In our department, carbohydrate counting is taught starting from diagnosis, children with T1D and their families are encouraged to be an active part of insulin dose adjustments and food management from the very beginning, correcting glucose elevation >145 mg/dl if possible, going to bed with normal glucose, and avoiding snacks unless necessary are emphasized as routine practices. We observe that the previously mentioned "10 Basic Recommendations" (15), which are easy to keep in mind, and its written form in the "Individual Treatment Plan" enable families of children with T1D to follow a roadmap and start by knowing what to do and why, which, together with the information provided by the sensors, facilitates their mastery. We think that this "mastering" process had a significant impact on the relatively better metabolic results we obtained and that they adhered to their T1D treatment routines with the motivation they gained from seeing success and provided a "positive cycle". At this point, we would like to point out that it is also important that we focus on helping families overcome the fear of hypoglycemia and glucagon injection (28,29) and that we have an educational approach that enables them to manage diabetes with knowledge, not fear.

One limitation of this study is that not all HbA1c measurements were performed at the same intervals due to its retrospective design. Since the study was conducted in a private hospital, not all cases were able to attend follow-up visits every three months, and HbA1c measurements could not be obtained at every visit. One possible reason for these less frequent visits may be the financial burden associated with receiving care in a private setting; however, we do not have direct evidence to confirm this. In addition, factors such as family education, sociocultural background, and acceptance of the diabetes diagnosis may also influence glycemic control. Due to the retrospective design of the study, data on the educational, sociocultural, and socioeconomic characteristics of the families were not available in the outpatient clinic records, and thus their potential impact could not be evaluated. Furthermore, no validated questionnaires or assessment tools were used to evaluate the level of diabetes acceptance by the children or their families. These were acknowledged as important limitations of the study. Additionally, since the families attending this center generally have middle and upper socio-economic level, the data may not reflect the entire country. When the cases were evaluated according to the duration of use of diabetes technologies, it was observed that glycemic control was worse in those who used diabetes technologies for a longer period of time. In this respect, the lack of longer follow-up data can be considered as another limitation of this study. However, as mentioned in the introduction, these results can help us build our own national program.

In conclusion, although the use of technology, especially CGM, has made a landmark difference in the treatment of T1D, there is a need for holistic approaches that focus on the behaviors of people with T1D, especially nutrition, and diabetes teams to ensure this.

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Data Availability:

All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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References

1. American Diabetes Association Professional Practice Committee. 14. Children and Adolescents: Standards of Care in Diabetes-2024. Diabetes Care. 2024 Jan 1;47(Suppl 1):S258-S281. doi: 10.2337/dc24-S014

2. de Bock M, Codner E, Craig ME, et al. ISPAD Clinical Practice Consensus Guidelines 2022: Glycemic targets and glucose monitoring for children, adolescents, and young people with diabetes. Pediatr Diabetes. 2022 Dec;23(8):1270-1276.

3. Anderzén J, Hermann JM, Samuelsson U, et al. International benchmarking in type 1 diabetes: Large difference in childhood HbA1c between eight high-income countries but similar rise during adolescence-A quality registry study. Pediatr Diabetes. 2020 Jun;21(4):621-627. doi: 10.1111/pedi.13014.

4. Sandy JL, Tittel SR, Rompicherla S, et al.; Australasian Diabetes Data Network (ADDN); T1D Exchanged Quality Improvement Collaborative (T1DX-QI); Prospective Diabetes Follow-Up Registry Initiative (DPV). Demographic, Clinical, Management, and Outcome Characteristics of 8,004 Young Children With Type 1 Diabetes. Diabetes Care. 2024 Feb 2:dc231317. doi: 10.2337/dc23-1317.

5. Dovc K, Telic SS, Lusa L, et al. Improved metabolic control in pediatric patients with type 1 diabetes: a nationwide prospective 12-year time trends analysis. Diabetes Technol Ther. 2014 Jan;16(1):33-40.

6. Phelan H, King B, Anderson D, et al. Young children with type 1 diabetes can achieve glycemic targets without hypoglycemia: Results of a novel intensive diabetes management program. Pediatr Diabetes. 2018 Jun;19(4):769-775. doi: 10.1111/pedi.12644.

7. Albanese-O'Neill A, Grimsmann JM, Svensson AM, et al. Changes in HbA1c Between 2011 and 2017 in Germany/Austria, Sweden, and the United States: A Lifespan Perspective. Diabetes Technol Ther. 2022 Jan;24(1):32-41. doi: 10.1089/dia.2021.0225.

8. Bratke H, Biringer E, Ushakova A, et al. Ten Years of Improving Glycemic Control in Pediatric Diabetes Care: Data From the Norwegian Childhood Diabetes Registry. Diabetes Care. 2024 Apr 22:dc240086. doi: 10.2337/dc24-0086. Epub ahead of print. PMID: 38648259.

9. Prahalad P, Ding VY, Zaharieva DP, et al. Teamwork, Targets, Technology, and Tight Control in Newly Diagnosed Type 1 Diabetes: the Pilot 4T Study. J Clin Endocrinol Metab. 2022 Mar 24;107(4):998-1008.

10. Zaharieva DP, Bishop FK, Maahs DM; 4T study research team. Advancements and future directions in the teamwork, targets, technology, and tight control-the 4T study: improving clinical outcomes in newly diagnosed pediatric type 1 diabetes. Curr Opin Pediatr. 2022 Aug 1;34(4):423-429.

11. Simsek DG, Aycan Z, Özen S, et al. Diabetes care, glycemic control, complications, and concomitant autoimmune diseases in children with type 1 diabetes in Turkey: a multicenter study. J Clin Res Pediatr Endocrinol. 2013;5(1):20-6.

12. Hatun Ş, Demirbilek H, Darcan Ş, et al. Turkish Pediatric Diabetes Research Group. Evaluation of therapeutics management patterns and glycemic control of pediatric type 1 diabetes mellitus patients in Turkey: A nationwide cross-sectional study. Diabetes Res Clin Pract. 2016 Sep; 119:32-40.
13. Şahin NM, Child and Adolescent Type 1 Diabetes Cohort Study in Turkey 2018-2023 Data. 3rd Child and Adolescent Diabetes Symposium, 2023
14. Battelino T, Danne T, Bergenstal RM, et al. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations From the International Consensus on Time in Range. Diabetes Care. 2019 Aug;42(8):1593-1603.
15. Hatun S, Gokce T, Can E, et al. Current Management of Type 1 Diabetes in Children: Guideline-based Expert Opinions and Recommendations. J Clin Res Pediatr Endocrinol. 2024 Mar 15. doi: 10.4274/jcrpe.galenos.2024.2024-1-15.
16. Mortensen HB, Hougaard P, Swift P, et al; Hvidoere Study Group on Childhood Diabetes. New definition for the partial remission period in children and adolescents with type 1 diabetes. Diabetes Care. 2009 Aug;32(8):1384-90. doi: 10.2337/dc08-1987. Epub 2009 May 12. PMID: 19435955; PMCID: PMC2713624.
17. Phillip M, Nimri R, Bergenstal RM, et al. Consensus Recommendations for the Use of Automated Insulin Delivery Technologies in Clinical Practice. Endocr Rev. 2023 Mar 4;44(2):254-280.
18. Arrieta A, Battelino T, Scaramuzza AE, et al. Comparison of MiniMed 780G system performance in users aged younger and older than 15 years: Evidence from 12 870 real-world users. Diabetes Obes Metab. 2022 Jul;24(7):1370-1379.
19. Castañeda J, Arrieta A, van den Heuvel T, et al. Time in Tight Glucose Range in Type 1 Diabetes: Predictive Factors and Achievable Targets in Real-World Users of the MiniMed 780G System. Diabetes Care. 2023 Dec 19:dc231581. doi: 10.2337/dc23-1581.
20. Teo E, Hassan N, Tam W, et al. Effectiveness of continuous glucose monitoring in maintaining glycaemic control among people with type 1 diabetes mellitus: a systematic review of randomised controlled trials and meta-analysis. Diabetologia. 2022 Apr;65(4):604-619. doi: 10.1007/s00125-021-05648-4. Epub 2022 Feb 9. PMID: 35141761.
21. Hásková A, Radovnická L, Petruželková L, et al. Real-time CGM Is Superior to Flash Glucose Monitoring for Glucose Control in Type 1 Diabetes: The CORRIDA Randomized Controlled Trial. Diabetes Care. 2020 Nov;43(11):2744-2750. doi: 10.2337/dc20-0112. Epub 2020 Aug 28. PMID: 32859607; PMCID: PMC7576432.
22. Corathers SD, DeSalvo DJ. Therapeutic Inertia in Pediatric Diabetes: Challenges to and Strategies for Overcoming Acceptance of the Status Quo. Diabetes Spectr. 2020 Feb;33(1):22-30. doi: 10.2337/ds19-0017. PMID: 32116450; PMCID: PMC7026749.
23. Šumník Z, Pavlíková M, Pomahačová R, et al; ČENDA Project Group. Use of continuous glucose monitoring and its association with type 1 diabetes control in children over the first 3 years of reimbursement approval: Population data from the ČENDA registry. Pediatr Diabetes. 2021 May;22(3):439-447.
24. Addala A, Ding V, Zaharieva DP, et al. Teamwork, Targets, Technology, and Tight Control (4T) Study Group. Disparities in Hemoglobin A1c Levels in the First Year After Diagnosis Among Youths With Type 1 Diabetes Offered Continuous Glucose Monitoring. JAMA Netw Open. 2023 Apr 3;6(4):e238881. doi: 10.1001/jamanetworkopen.2023.8881.
25. Alonso GT, Fink K, Maffeis C, et al. Variation in nutrition education practices in SWEET pediatric diabetes centers-an international comparison. Pediatr Diabetes. 2021 Mar;22(2):215-220.
26. Cengiz E. Automated Insulin Delivery in Children with Type 1 Diabetes. Endocrinol Metab Clin North Am. 2020 Mar;49(1):157-166.
27. Corathers SD, DeSalvo DJ. Therapeutic Inertia in Pediatric Diabetes: Challenges to and Strategies for Overcoming Acceptance of the Status Quo. Diabetes Spectr. 2020 Feb;33(1):22-30. doi: 10.2337/ds19-0017.
28. Van Name MA, Hilliard ME, Boyle CT, et al. Nighttime is the worst time: Parental fear of hypoglycemia in young children with type 1 diabetes. Pediatr Diabetes. 2018 Feb;19(1):114-120.
29. Muradoğlu S, Yeşiltepe Mutlu G, Gökçe T, et al. An Evaluation of Glucagon Injection Anxiety and Its Association with the Fear of Hypoglycemia among the Parents of Children with Type 1 Diabetes. J Clin Res Pediatr Endocrinol. 2021 Aug 23;13(3):285-292.

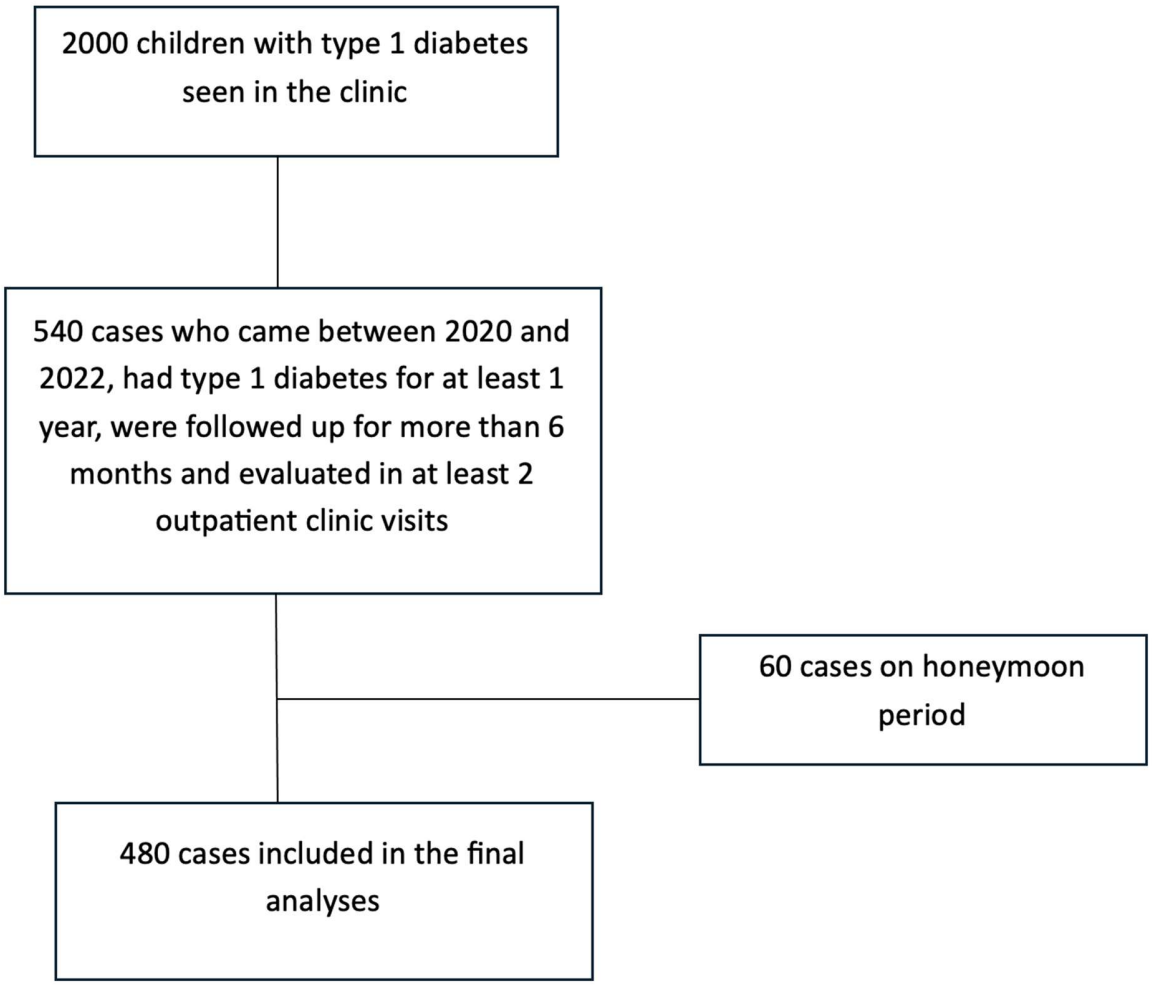

Figure 1. The flow chart of the cases

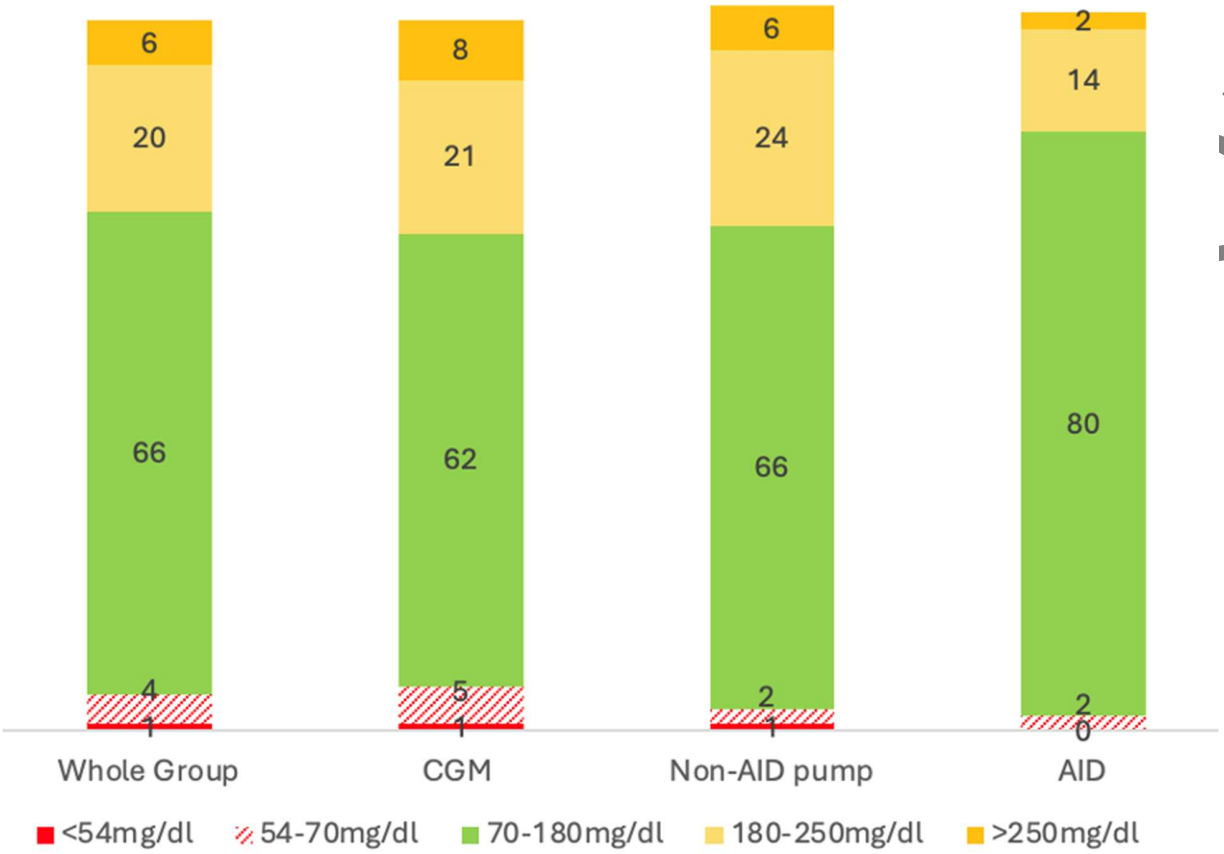

Figure 2. CGM metric values in cases with sensor data

Table 1. Demographic features and metabolic parameters of the cases in all groups	
Number of the participants	480
Gender (Male) (%)	50
Age at diagnosis of diabetes (years), mean ± SD	6.9 ± 3.9
Diabetes duration in the first visit (years), median (IQR)	0.4 (0.06 – 2.4)
Follow-up time (years), mean ± SD	2.7 ± 1.5
Number of visits, mean ± SD	4.2 ± 1.7
TDI (U/kg/day), mean ± SD	0.8 ± 0.2
HbA1c in the first visit (%), mean ± SD	7.8±1.5
Hba1c (%) †, mean ± SD median (IQR)	7.3 ± 1.1‡ 7.1 (6.6 – 7.8)
Number of HbA1c measurements, mean ± SD	3.1 ± 1.5

HbA1c <6.5% (%)	21
HbA1c 6.6-7% (%)	22
Hba1c 7.1-8% (%)	37
Hba1c 8.1-9% (%)	13
HbA1c >%9 (%)	7
TIR (70-180mg/dl) (%), mean ± SD	66.2 ± 13.8
TAR 1 (180-250mg/dl) (%), mean ± SD	20.2 ± 9.3
TAR 2 (>250mg/dl) (%), median (IQR)	6 (2 – 11.7)
TBR 1 (54-70mg/dl) (%), median (IQR)	4 (2 – 7)
TBR 2 (<54mg/dl) (%), median (IQR)	1 (0 – 2)
Mean SG (mg/dl), mean ± SD	149.5 ± 23
CV (%), mean ± SD	39 ± 7
GMI (%), mean ± SD	6.8 ± 0.5

*CV: Coefficient of variation, GMI: glucose management indicator, Mean SG: mean sensor glucose, TAR: Time above range, TBR: Time below range, TDI: total daily insulin, TIR: Time in range
† The HbA1c value given here is the average of HbA1c values during follow-up
‡ There was a statistically significant difference between Hba1c at baseline and mean Hba1c (p<0.001).

Table 2. Metabolic parameters of the patients according to treatment modalities and glucose monitoring methods

	MDI+ CGM n: 203	non-AID pump users n: 77	AID users n: 59	p
HbA1c (%), mean±SD†,‡	7.1±0.9	7.3±1	7±0.7	0.060
HbA1c <%6,5 (%)§	25	16	24	<0.001
HbA1c <%6.6-7 (%)§	24	26	34	<0.001
Hba1c %7.1-8 (%)§	37	39	36	<0.001
Hba1c %8.1-9 (%)§	10	13	5	<0.001
HbA1c >%9 (%)§	4	5	0	<0.001
TIR (70-180mg/dl) (%), mean±SD ‡	62±12.6	66.3±13.5	79.6±8.5	<0.001
TIR >% 70 (%)§	29	45	88	<0.001
TAR 1 (180-250mg/dl) (%), mean±SD‡	21.1±8.4	24.2±11.2	13.7±6.5	<0.001

TAR 2 (>250mg/dl) (%), median, (IQR)¶	8 (3 – 13)	6 (2 – 10.5)	2 (1 – 4)	<0.001
TBR 1 (54-70mg/dl) (%), median, (IQR)¶	5 (3 – 8)	2 (1 – 4)	2 (1 – 4)	<0.001
TBR 2 (<54mg/dl) (%), median, (IQR)¶	1 (1 – 3)	1 (0 – 1)	0 (0 – 1)	<0.001
Mean SG (mg/dl), mean±SD‡	152.2±23.9	155.3±22.1	135.2±14.1	<0.001
CV (%), mean±SD‡	41.5±6.9	37.4±5.4	33.7±5.1	<0.001
CV being <%36, (%)§	21	34	66	<0.001
GMI, (%), mean±SD‡	6.9±0.6	7±0.5	6.5±0.3	<0.001

*AID: Automated insulin delivery, CGM: continuous glucose monitoring, CV: Coefficient of variation, MDI: multiple dose insulin, GMI: glucose management indicator, IQR: inter quartile range, mean SG: mean sensor glucose, TAR: Time above range, TBR: Time below range, TIR: Time in range

†The HbA1c value given here is the average of HbA1c values during follow-up

‡ Levene analysis of variance was performed due to differences in sample size between groups. Welch ANOVA test was performed for all parameters except CV since Levene's variance was not equal between the groups. One-Way ANOVA was performed due to the equality of variance between the groups in CV. The Games-Howell test was used as post hoc analysis to determine which groups the difference occurred between. There was a significant difference in CV between all three groups. For other parameters, there was a significant difference between AID users and the other two groups, but no significant difference between CGM with MDI users and non-AID pump users.

§ The difference between the groups was analyzed using the Chi square test.

¶ The significance of the difference between groups was assessed using Kruskall-Wallis analysis. Mann-Whitney U analysis with Bonferroni correction was performed to determine which groups the difference occurred between. The difference in TAR2 was between AID users and the other two groups. The difference in TBR1 and TBR2 was between CGM with MDI users and the other two groups.

Table 3. Metabolic parameters according to the type of CGM used

	f-CGM n: 140	rt-CGM n: 63	p
HbA1c (%), mean±SD	7.2±0.8	6.7±0.7	<0.001
TIR (70-180mg/dl) (%), mean±SD	59.2±11.7	68.1±12.4	<0.001
TAR 1 (180-250mg/dl) (%), mean±SD	21.8±8.6	19.4±7.8	0.038
TAR 2 (>250mg/dl) (%), median, (IQR)	9 (3 – 14)	7 (3 – 12)	0.091
TBR 1 (54-70mg/dl) (%), median, (IQR)	5 (4 – 8)	4 (2 – 6)	<0.001

TBR 2 (<54mg/dl) (%), median, (IQR)	2 (1 – 4)	1 (1 – 1)	0.00
Mean SG (mg/dl), mean±SD	153.8±24.8	148.7±21.4	0.175
CV (%), mean±SD	42.6±7	38.6±5.5	0.001
GMI (%), mean±SD	6.9±0.6	6.8±0.5	0.222
TIR (70-180mg/dl) being >%70 (%)	21	46	0.001
TAR (180-250 mg/dl) being <%25 (%)	36	48	0.121
TBR (<70mg/dl) being <%5 (%)	38	57	0.018
CV being <%36 (%)	18	30	0.082

*CV: Coefficient of variation, f-CGM: flash-continuous glucose monitoring, GMI: glucose management indicator, IQR: inter quartile range, mean SG: mean sensor glucose, rt-CGM: real-time continuous glucose monitoring, TAR: Time above range, TBR: Time below range, TIR: Time in range

†The difference between the groups was analyzed with independent sample t test for HbA1c, TIR, TAR 1, Mean SG, CV and GMI; with Mann Whitney U test for TAR2, TBR 1 and TBR2, and with Chi Square test for TIR >70%, TAR >25%, TBR <5% and CV <36%.

Table 4. Metabolic parameters according to the duration of diabetes technology use

	≤2 years n: 132	>2 years n: 207	p
HbA1c (%), mean±SD	6.9 ± 0.8	7.3 ± 0.9	**<0.001**
TIR (70-180mg/dl) (%), mean±SD	68.2 ± 13.8	64.6 ± 13.6	**0.026**
TAR 1 (180-250mg/dl) (%), mean±SD	19.1 ± 9.9	21.1 ± 8.8	0.076
TAR 2 (>250mg/dl) (%), median, (IQR)	4 (2 – 10)	7 (2 – 13)	**0.032**
TBR 1 (54-70mg/dl) (%), median, (IQR)	4 (2 – 6)	4 (2 – 7)	0.671
TBR 2 (<54mg/dl) (%), median, (IQR)	1 (1 – 2)	1 (0 – 2)	0.312
Mean SG (mg/dl), mean±SD	145.4 ± 22.7	152.6 ± 22.9	**0.007**
CV (%), mean±SD	38.5 ± 6.9	39.4 ± 7.1	0.310
GMI (%), mean±SD	6.7 ± 0.6	6.9 ± 0.5	**0.019**
TIR (70-180mg/dl) being >%70 (%)	49	39	0.067

TAR (180-250 mg/dl) being <%25 (%)	58	44	**0.018**
TBR (<70mg/dl) being <%5 (%)	53	57	0.428
CV being <%36 (%)	35	33	0.728

*CV: Coefficient of variation, f-CGM: flash-continuous glucose monitoring, GMI: glucose management indicator, IQR: inter quartile range, mean SG: mean sensor glucose, rt-CGM: real-time continuous glucose monitoring, TAR: Time above range, TBR: Time below range, TIR: Time in range

†The difference between the groups was analyzed with independent sample t test for HbA1c, TIR, TAR 1, Mean SG, CV and GMI; with Mann Whitney U test for TAR2, TBR 1 and TBR2, and with Chi Square test for TIR >70%, TAR >25%, TBR <5% and CV <36%.