Effectiveness and Safety of Control-IQ Technology in Preschool and School-Aged Children with Type 1 Diabetes: A Real-World Multicenter Study

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INTRODUCTION

Achieving and maintaining optimal glycemic control from the onset of type 1 diabetes (T1D) is crucial in pediatric care, especially in early childhood when the developing brain is highly vulnerable to both hypo- and hyperglycemia [1-3]. Hyperglycemia during early childhood increases the risk of long-term vascular complications, while severe hypoglycemia may impair neurocognitive development, causes family anxiety, and complicates social integration [4-5]. Although automated insulin delivery (AID) systems have demonstrated efficacy in controlled trials, real-world evidence in children under six years of age, particularly involving off-label use, remains limited. The Control-IQ (CIQ) algorithm, integrated into the Tandem t:slim X2 insulin pump, has shown benefits in adolescents and school-aged children [6-10]. However, few studies have evaluated its long-term use in children under six in routine clinical practice.

OBJECTIVE

This study aimed to compare the real-world effectiveness and safety of the CIQ system in two pediatric age groups—children aged 0.5–5 years and children aged 6–10 years—over an 18-month follow-up period. We evaluated effectiveness in terms of glycemic control (% of time in glucose range 70–180 mg/dL [TIR], % of time in glucose range 70–140 mg/dL [TITR], and HbA1c) and safety in term of adverse events (diabetic ketoacidosis [DKA], hyperglycemia and severe hypoglycemia).

METHODS

This prospective, multicenter observational study used retrospective data from 32 Italian pediatric diabetes centers. Eligible participants had T1D diagnosed ≥ 6 months, , were < 11 years old at CIQ initiation, and had continuous glucose monitoring (CGM) data available via Glooko® or Clarity® software at least every 6 months during the 18-month follow-up. Children with non-T1D or aged >10 years at CIQ start were excluded. Participants were stratified by age at CIQ initiation (0.5–5 and 6–10 years). At CIQ initiation (baseline) sex, presence of celiac disease or thyroiditis and parents' age, nationality and education, were collected. HbA1c, BMI z-score, CGM-derived data (TIR, TITR, % of time spent in glucose ranges: <54 mg/dL, 54-<70 mg/dL, 180-<250 mg/dL, >250 mg/dL, Glucose Monitoring Indicators and coefficient of variation of glucose), Glycemia, Standard Deviation of Glycemia [SD] and DKA episodes were assessed at baseline, 6, 12, and 18 months. Descriptive statistics were used for baseline comparisons. Chi-square or t tests evaluated group differences. Trend over time points in TIR, TITR, and HbA1c were analysed using mixed-effects models for repeated measures, adjusted by age group, sex, time from diagnosis to CIQ initiation, DKA at onset and parents' socio-economic characteristics (at least one non-Italian parent, parents' education). A sequential difference contrast was used to model time; interaction between time and age groups was evaluated. Only children with complete data on the outcomes at all four time points were included in these models.

DOI: 10.54103/2282-0930/29451

Safety outcomes included the proportions of DKA and severe hypoglycaemias occurring during 18-month follow-up.

RESULTS

Of the 334 children enrolled, 253 (106 aged 0.5–5; 147 aged 6–10) had complete data on the outcomes and were included in longitudinal analyses. At T1D diagnosis, a higher prevalence of thyroiditis in the older group was found, and no significant sociodemographic differences. At CIQ initiation, younger children had a significantly shorter time from diagnosis to CIQ initiation (1.36 vs 2.61 years, p<0.001), higher HbA1c (8.3%% vs 7.7%, p=0.020) and higher glycaemic variability (SD 63.3 mg/dL vs 58.3 mg/dL, p = 0.023) while TIR, TITR, and the other CGM-derived data were comparable.

Longitudinal analysis (Figure 1) showed significant improvement in both groups 6 months after CIQ initiation: TIR increased by 6.62% (95% CI: 4.89–8.36) and TITR by 5.63% (95% CI: 3.61–7.66), corresponding to over 80 additional minutes/day spent in target ranges. These improvements were sustained at 12 and 18 months. HbA1c decreased by an average of 0.82% (95% CI: −1.01 to −0.62) in the first 6 months, remaining stable thereafter. No significant interaction between time and age groups was observed, indicating similar trends in both cohorts. Having at least one non-Italian parent was significantly associated with lower TIR (-5.82%, 95% CI: -10.33 to -1.31) and higher HbA1c levels (0.31%, 95% CI: 0.01 to 0.63). A high parental education level (university or higher vs. up to lower secondary education) was associated with higher TIR (8.61%, 95% CI: 3.03–14.18) and lower HbA1c levels (−0.42%, 95% CI: −0.78 to −0.06). Age at CIQ initiation, time from diagnosis to CIQ initiation, DKA at diagnosis, and sex were not significant predictor.

Regarding safety, no severe hypoglycaemia episodes were reported in the younger group, and only one occurred in the older group after 12 months. A single DKA episode was recorded in a child under six. Moreover, CGM-derived data indicated that time spent in hypoglycaemia (<54 and 54–69 mg/dL) remained consistently below clinically relevant thresholds (<1% and <3%, respectively).

CONCLUSION

In this large real-world cohort of young children with T1D, the CIQ system demonstrated consistent and sustained improvements in glycaemic outcomes over 18 months, with minimal adverse events. Significant gains in TIR, TITR, and HbA1c were observed in both age groups, particularly in the first 6 months after CIQ initiation. These benefits were maintained long-term, regardless of initial glycaemic status and presence of DKA at diagnosis. The system proved safe even in children under six, supporting its current use in off-label settings with appropriate clinical oversight. Our findings reinforce the value of early AID adoption to optimize long-term metabolic outcomes in pediatric T1D.

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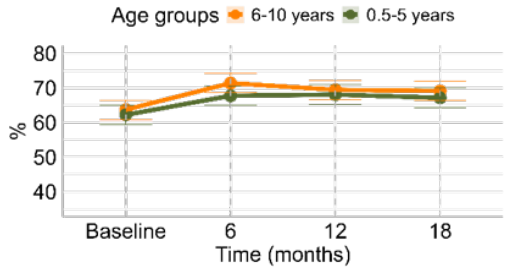
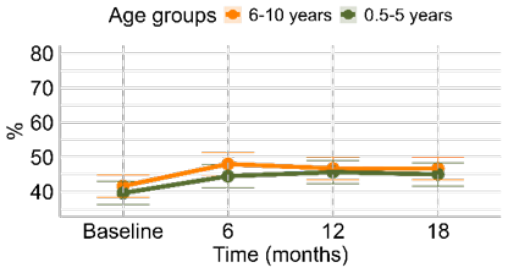
DOI: 10.54103/2282-0930/29451

Figure 1. Effect of time on Time In Range, Time In Tight Range and HbA1c between age groups.

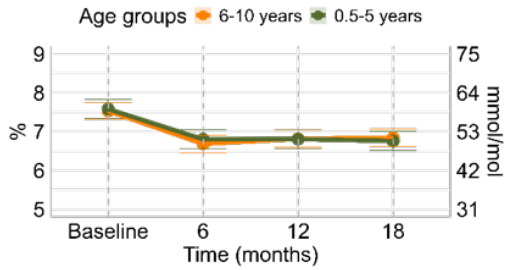
Panel A: TIR 70-180 mg/dL



Panel B: TITR 70-140 mg/dL



Panel C: HbA1c



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