

In Adults with Type 1 Diabetes, is the Artificial Pancreas System More Effective than Open-loop Systems in Controlling Blood Glucose?

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Abstract: *Background:* Despite advances in continuous glucose monitoring (CGM) and insulin pump therapy, many adults with type 1 diabetes (T1D) do not consistently achieve recommended glycemic targets. Automated insulin delivery (AID), often referred to as the artificial pancreas (AP), integrates CGM, an insulin pump, and a control algorithm to adjust insulin delivery in real time. *Objective:* To summarize contemporary evidence comparing AP/AID (closed-loop or hybrid closed-loop) with open-loop approaches (e.g., sensor-augmented pump therapy or user-directed insulin dosing) for glycemic control in adults with T1D. *Methods:* We synthesized evidence from recent randomized controlled trials (RCTs) and meta-analyses in adults with T1D, focusing on clinically meaningful CGM-derived metrics (time in range [TIR], time below range), HbA1c, and safety outcomes. Reporting principles align with PRISMA 2020 where applicable. *Results:* Across modern RCTs and meta-analyses, AP/AID consistently improves TIR and reduces hyperglycemia compared with open-loop strategies, without increasing hypoglycemia. Key trials in older adults show clinically relevant gains in TIR with closed-loop systems versus sensor-augmented pump therapy. Meta-analytic evidence supports improved TIR and modest HbA1c reductions with closed-loop compared with open-loop approaches. *Conclusion:* In adults with T1D, AP/AID systems are more effective than open-loop regimens in improving glycemic control, offering better TIR and comparable or improved hypoglycemia safety profiles.

Keywords: Type 1 diabetes; Artificial pancreas; Automated insulin delivery; Closed-loop; Hybrid closed-loop; Sensor-augmented pump; Time in range; Continuous glucose monitoring.

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1. Background

Type 1 diabetes is a chronic autoimmune condition characterized by pancreatic β -cell destruction and lifelong insulin dependence. Although it represents a smaller proportion of global diabetes burden, the number of people living with T1D is substantial and projected to increase^[1]. Achieving and sustaining near-target glycaemia reduces the risk of microvascular and macrovascular complications and improves quality of life; however, daily self-

management remains complex, particularly in the setting of variable meals, exercise, illness, and stress.

Open-loop therapy, whether via multiple daily injections or pump therapy guided by user decisions has improved substantially with real-time CGM and sensor-augmented pumps. Yet, persistent glycemic variability, nocturnal dysglycemia, and fear of hypoglycemia continues to limit target attainment for many adults. Recent data also suggest that severe hypoglycemia and impaired awareness can persist even among technology users, highlighting the unmet need for safer, more stable glucose control strategies ^[2].

The artificial pancreas (AP), more broadly conceptualized as automated insulin delivery (AID), combines CGM, an insulin pump, and an algorithm that automatically adjusts insulin delivery. Most commercially available systems are hybrid closed-loop: they automate basal adjustments and may provide automated corrections, but still require user-initiated meal boluses. Contemporary clinical evidence indicates that these systems can increase TIR, reduce hyperglycemia, and maintain or reduce hypoglycemia compared with open-loop regimens ^[3].

2. Methods

This publication-form synthesis focuses on adult populations (≥ 18 years) with T1D and compares AP/AID (closed-loop or hybrid closed-loop) to open-loop strategies (e.g., sensor-augmented pump therapy or user-directed insulin dosing). This study prioritized evidence from:

- (1) Randomized controlled trials conducted under free-living/outpatient conditions; and
- (2) Systematic reviews/meta-analyses evaluating closed-loop versus open-loop approaches in adults with T1D.

Primary outcomes of interest were CGM-derived metrics, particularly TIR (typically 70–180 mg/dL [3.9–10.0 mmol/L]), time above range, and time below range, as well as HbA1c and safety outcomes (severe hypoglycemia, diabetic ketoacidosis, device-related adverse events). Reporting and synthesis principles follow PRISMA 2020 guidance when applicable ^[4].

3. Results

3.1. Glycemic effectiveness

Across contemporary RCTs in adults, AP/AID improves glycemic control compared with open-loop strategies, with the most consistent benefits observed in TIR. In a randomized crossover trial in older adults with long-duration T1D (ORACL), closed-loop insulin delivery improved CGM TIR compared with sensor-augmented pump therapy, while maintaining a favorable safety profile ^[5]. Findings from an open-label, multicenter randomized crossover study in older adults similarly demonstrated superior glycemic outcomes with hybrid closed-loop versus sensor-augmented pump therapy, achieved without an increased risk of hypoglycemia ^[6].

These trial-level findings align with meta-analytic evidence. A systematic review and meta-analysis of RCTs in adults reported that closed-loop systems increase TIR and reduce HbA1c relative to sensor-augmented pump therapy, with no excess hypoglycemia ^[7]. Collectively, the evidence supports a clinically meaningful improvement in daily glucose stability, commonly expressed as greater time spent within target range and less time spent above range, when insulin delivery is partially automated by an algorithm.

3.2. Hypoglycemia and safety

A critical question for AP/AID is whether tighter control increases hypoglycemia risk. Across recent RCTs, closed-loop strategies generally do not increase time below range and may reduce exposure to hypoglycemia due to predictive low-glucose management and automated insulin modulation ^[5,6]. The safety signals reported in these trials are reassuring, with low rates of severe hypoglycemia and no clear increase in ketoacidosis in the controlled trial settings.

At a population level, severe hypoglycemia and impaired awareness remain clinically relevant challenges for adults with T1D, including technology users, reinforcing the importance of solutions that improve control without trading off safety ^[2]. The available trial evidence indicates that AP/AID can deliver this balance for many adults, though outcomes depend on user training, device wear adherence, and appropriate system settings.

3.3. Patient-centered outcomes and implementation considerations

Beyond glycemic endpoints, treatment burden and user experience influence real-world effectiveness. Observational and follow-up studies suggest that advanced hybrid closed-loop use can be associated with improvements in quality-of-life domains among adults, including those previously naïve to advanced diabetes technology ^[8]. These patient-centered outcomes are consistent with the conceptual promise of AID: reducing cognitive load associated with continuous self-management while improving glucose stability.

Health-system factors, including training, follow-up support, and telemedicine-enabled workflows, may further influence outcomes. Telemedicine interventions in T1D have been associated with improvements in diabetes-related outcomes in systematic review evidence, supporting the plausibility that structured remote support could complement AP/AID adoption, particularly during initiation and optimization phases ^[9].

4. Discussion

The current evidence base indicates that AP/AID systems provide superior glycemic control compared with open-loop regimens in adults with T1D, primarily via improvements in TIR and reductions in hyperglycemia, without increasing hypoglycemia ^[5-7]. These benefits have been demonstrated in free-living conditions and in higher-risk groups such as older adults, who may be particularly vulnerable to severe hypoglycemia and its consequences ^[5,6].

Several considerations are important for interpretation. First, many technology trials are open-label by necessity, which may affect subjective outcomes; however, primary glycemic endpoints are typically derived from CGM data and are objective. Second, trial populations may be more motivated and supported than typical real-world cohorts, potentially inflating adherence and outcomes. Third, systems vary (algorithm features, automation level, correction boluses, usability), so effect sizes may differ across devices and settings ^[10]. Comprehensive clinical reviews highlight rapid device evolution and increasing automation, which may further enhance effectiveness over time ^[3].

From an implementation standpoint, the observed advantages of AP/AID strengthen the argument for broader access, particularly for adults who remain above target despite optimized open-loop therapy, those with problematic hypoglycemia, and individuals with high day-to-day glycemic variability. Nevertheless, persistent severe hypoglycemia risk in some technology users underscores that device adoption alone may be insufficient; structured education, follow-up and telemedicine-enabled optimization may be required to maximize benefit ^[2,9].

5. Conclusion

In adults with type 1 diabetes, artificial pancreas/automated insulin delivery systems are more effective than open-loop approaches for controlling blood glucose. Contemporary RCT and meta-analytic evidence shows consistent improvements in time in range and reductions in hyperglycemia without increased hypoglycemia, supporting AP/AID as an important therapeutic advancement in adult T1D management.

Disclosure statement

The author declares no conflict of interest.

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