Medical Policy

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Title: Artificial Pancreas Device Systems

Related Policy:	*Continuous Glucose Monitoring Systems*

Professional	**Institutional**
Original Effective Date: March 6, 2015	Original Effective Date: March 6, 2015
Revision Date(s): March 6, 2015; February 3, 2016; October 1, 2016; January 18, 2017; January 1, 2018; March 1, 2018; November 7, 2018; January 4, 2019; May 21, 2019; January 1, 2020, May 22, 2020; June 3, 2021; June 1, 2022	Revision Date(s): March 6, 2015; February 3, 2016; October 1, 2016; January 18, 2017; January 1, 2018; March 1, 2018; November 7, 2018; January 4, 2019; May 21, 2019; January 1, 2020, May 22, 2020; June 3, 2021; June 1, 2022
Current Effective Date: June 1, 2022	Current Effective Date: June 1, 2022

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Populations	Interventions	Comparators	Outcomes
Individuals: • With type 1 diabetes	Interventions of interest are: • Artificial pancreas device system with a low-glucose suspend feature	Comparators of interest are: • Non-integrated continuous glucose monitoring plus insulin pump	Relevant outcomes include: • Symptoms • Change in disease status • Morbid events • Resource utilization

Populations	Interventions	Comparators	Outcomes
		• Self-monitoring blood glucose and multiple dose insulin injection therapy	• Treatment-related morbidity
Individuals: • With type 1 diabetes	Interventions of interest are: • Artificial pancreas device system with a hybrid closed-loop insulin delivery system	Comparators of interest are: • Non-integrated continuous glucose monitoring plus insulin pump • Self-monitoring blood glucose and multiple dose insulin injection therapy • Artificial pancreas device system with a low-glucose suspend feature	Relevant outcomes include: • Symptoms • Change in disease status • Morbid events • Resource utilization • Treatment-related morbidity

DESCRIPTION

Automated insulin delivery systems, also known as artificial pancreas device systems, link a glucose monitor to an insulin infusion pump that automatically takes action (e.g., suspends or adjusts insulin infusion) based on the glucose monitor reading. These devices are proposed to improve glycemic control in patients with insulin-dependent diabetes, in particular, control of nocturnal hypoglycemia.

OBJECTIVE

The objective of this evidence review is to determine whether artificial pancreas device systems improve the net health outcome in patients with type 1 diabetes compared with standard glucose monitoring, either continuous glucose monitoring (CGM) or self-monitoring of blood glucose (SMBG), plus an insulin pump or multiple insulin injection therapy.

BACKGROUND

Diabetes and Glycemic Control

Tight glucose control in patients with diabetes has been associated with improved health outcomes. The American Diabetes Association has recommended a glycated hemoglobin level below 7% for most patients. However, hypoglycemia, may place a limit on the ability to achieve tighter glycemic control. Hypoglycemic events in adults range from mild to severe based on a number of factors including the glucose nadir, the presence of symptoms, and whether the episode can be self-treated or requires help for recovery. Children and adolescents represent a population of type 1 diabetics who have challenges in controlling hyperglycemia and avoiding hypoglycemia. Hypoglycemia is the most common acute complication of type 1 diabetes.

Table 1 is a summary of selected clinical outcomes in type 1 diabetes clinical management and research.

Table 1. Outcome Measures for Type 1 Diabetes

Measure	Definition	Guideline type	Organization	Date
Hypoglycemia		Stakeholder survey, expert opinion with evidence review	Type 1 Diabetes Outcome Programa[1,]	2017
Level 1 Level 2 Level 3	Glucose < 70 mg/dl but ≥ 54 mg/dl Glucose < 54 mg/dl Event characterized by altered mental/physical status requiring assistance			
Hypoglycemia	Same as Type 1 Diabetes Outcome Programa	Professional Practice Committee with systematic literature review	ADA [2,]	2019
Hypoglycemia Clinical alert for evaluation and/or treatment Clinically important or serious Severe hypoglycemia	 Glucose < 70 mg/dl Glucose < 54 mg/dl Severe cognitive impairment requiring external assistance by another person to take corrective action	Clinical Practice Consensus	ISPAD [3,]	2018
Hyperglycemia Level 1 Level 2	 Glucose > 180 mg/dL and ≤250 mg/dL Glucose > 250 mg/dL		Type 1 Diabetes Outcome Programa[4,]	2017
Time in Range[b]	Percentage of glucose readings in the range of 70–180 mg/dL per unit of time		Type 1 Diabetes Outcome Programa	2017
Diabetic ketoacidosis (DKA)	Elevated serum or urine ketones > ULN Serum bicarbonate <15 mEq/L Blood pH <7.3		Type 1 Diabetes Outcome Programa[2,]	2017

ADA: American Diabetes Association, ISPAD: International Society for Pediatric and Adolescent Diabetes; ULN: upper limit of normal.
[a]Steering Committee: representatives from American Association of Clinical Endocrinologists (AACE), American Association Diabetes Educators, the American Diabetes Association (ADA), the Endocrine Society, JDRF International, The Leona M. and Harry B. Helmsley Charitable Trust, the Pediatric Endocrine Society, type 1 diabetes Exchange.
[b]Time in range: has also been adopted by researchers evaluating the precision and effectiveness of emerging glucose monitoring and automated insulin delivery technologies.

Treatment
Type 1 diabetes is caused by the destruction of the pancreatic beta cells which produce insulin, and the necessary mainstay of treatment is insulin injections. Multiple studies have shown that intensive insulin treatment, aimed at tightly controlling blood glucose, reduces the risk of long-term complications of diabetes, such as retinopathy and renal disease. Optimal glycemic control, as assessed by glycated hemoglobin, and avoidance of hyper- and hypoglycemic excursions have been shown to prevent diabetes-related complications. Currently, insulin treatment strategies include either multiple daily insulin injections or continuous subcutaneous insulin infusion with an insulin pump.

REGULATORY STATUS

The U.S. Food and Drug Administration (FDA) describes the basic design of an artificial pancreas device system as a continuous glucose monitoring linked to an insulin pump with the capability to automatically stop, reduce, or increase insulin infusion based on specified thresholds of measured interstitial glucose.[5,]

The artificial pancreas device system components are designed to communicate with each other to automate the process of maintaining blood glucose concentrations at or near a specified range or target and to minimize the incidence and severity of hypoglycemic and hyperglycemic events. An artificial pancreas device system control algorithm is embedded in software in an external processor or controller that receives information from the continuous glucose monitoring and performs a series of mathematical calculations. Based on these calculations, the controller sends dosing instructions to the infusion pump.

Different artificial pancreas device system types are currently available for clinical use. Sensor augmented pump therapy with low glucose suspend (suspend on low) may reduce the likelihood or severity of a hypoglycemic event by suspending insulin delivery temporarily when the sensor value reaches (reactive) a predetermined lower threshold of measured interstitial glucose. Low glucose suspension automatically suspends basal insulin delivery for up to 2 hours in response to sensor-detected hypoglycemia.

A sensor augmented pump therapy with predictive low glucose management (suspend before low) suspends basal insulin infusion with the prediction of hypoglycemia. Basal insulin infusion is suspended when sensor glucose is at or within 70 mg/dL above the patient-set low limit and is predicted to be 20 mg/dL above this low limit in 30 minutes. In the absence of a patient response, the insulin infusion resumes after a maximum suspend period of 2 hours. In certain circumstances, auto-resumption parameters may be used.

When a sensor value is above or predicted to remain above the threshold, the infusion pump will not take any action based on continuous glucose monitoring readings. Patients using this system still need to monitor their blood glucose concentration, set appropriate basal rates for their insulin pump, and give premeal bolus insulin to control their glucose levels.

A control-to-range system reduces the likelihood or severity of a hypoglycemic or hyperglycemic event by adjusting insulin dosing only if a person's glucose levels reach or approach predetermined higher and lower thresholds. When a patient's glucose concentration is within the specified range, the infusion pump will not take any action based upon continuous glucose

monitoring readings. Patients using this system still need to monitor their blood glucose concentration, set appropriate basal rates for their insulin pump, and give premeal bolus insulin to control their glucose levels.

A control-to-target system sets target glucose levels and tries to maintain these levels at all times. This system is fully automated and requires no interaction from the user (except for calibration of the continuous glucose monitoring). There are 2 subtypes of control-to-target systems: insulin-only and bihormonal (e.g., glucagon). There are no systems administering glucagon marketed in the United States.

An artificial pancreas device system may also be referred to as a "closed-loop" system. A closed-loop system has automated insulin delivery and continuous glucose sensing and insulin delivery without patient intervention. The systems utilize a control algorithm that autonomously and continually increases and decreases the subcutaneous insulin delivery based on real-time sensor glucose levels. There are no completely closed-loop insulin delivery systems marketed in the United States.

A hybrid closed-loop system also uses automated insulin delivery with continuous basal insulin delivery adjustments. However, at mealtime, the patient enters the number of carbohydrates they are eating in order for the insulin pump to determine the bolus meal dose of insulin. A hybrid system option with the patient administration of a premeal or partial premeal insulin bolus can be used in either control-to-range or control-to-target systems.

These systems are regulated by the FDA as class III device systems.

Table 2 summarizes the FDA-approved automated insulin delivery systems.

Table 2. FDA-Approved Automated Insulin Delivery Systems (Artificial Pancreas Device Systems)

Device	Age Indication	Manufacturer	Date Approved	PMA No./Device Code
MiniMed 530G System[a](open-loop, LGS)	≥16 y	Medtronic	Jul 2013	P120010/OZO
MiniMed 630G System with SmartGuard™[b](open-loop, LGS)	≥16 y ≥ 14 y	Medtronic	Aug 2016 Jun 2017	P150001/OZO P150001/S008
MiniMed 670G System[c] (HCL, LGS or PLGM)	≥14 y ≥7-13 y	Medtronic	Sep 2016 Jul 2018	P160017/OZP P160017/S031
MiniMed 770G System[d] (HCL)[6,]	≥2 y	Medtronic	Aug 2020	P160017/S076
t:slim X2 Insulin Pump with Basal-IQ Technology (LGS)[7,]	>6 y	Tandem	Jun 2018	P180008/OZO, PQF
t:slim X2 Insulin Pump with Control-IQ Technology (HCL)	>6y	Tandem	Dec 2019	DEN180058/QFG

FDA: U.S. Food and Drug Administration; LGS: low glucose suspend; OZO: Artificial Pancreas Device System, threshold suspend; OZP: Automated Insulin Dosing Device System, Single Hormonal Control; PMA: premarket approval; PLGM:

predictive low glucose management.
[a]MiniMed 530G System consists of the following devices that can be used in combination or individually: MiniMed 530G Insulin Pump, Enlite™ Sensor, Enlite™Serter, the MiniLink Real-Time System,
the Bayer Contour NextLink glucose meter, CareLink® Professional Therapy Management Software for Diabetes, and CareLink® Personal Therapy Management Software for Diabetes (at time of approval).
[b]MiniMed 630G System with SmartGuard™ consists of the following devices: MiniMed 630G Insulin Pump, Enlite® Sensor, One-Press Serter, Guardian® Link Transmitter System,
CareLink® USB, Bayer's CONTOUR ® NEXT LINK 2.4 Wireless Meter, and Bayer's CONTOUR® NEXT Test Strips (at time of approval).
[c]MiniMed 670G System consists of the following devices: MiniMed 670G Pump, the Guardian Link (3) Transmitter, the Guardian Sensor (3), One-Press Serter, and the Contour NEXT Link 2.4 Glucose Meter (at time of approval).
MiniMed 770G System consists of the following devices: MiniMed 770G Insulin Pump, the Guardian Link (3) Transmitter, the Guardian Sensor (3), one-press serter, the Accu-Chek Guide™ Link blood glucose meter, and the Accu-Chek Guide™ Test Strips.

The MiniMed 530G System includes a threshold suspend or low glucose suspend feature.[8,] The threshold suspend tool temporarily suspends insulin delivery when the sensor glucose level is at or below a preset threshold within the 60- to 90-mg/dL range. When the glucose value reaches this threshold, an alarm sounds. If patients respond to the alarm, they can choose to continue or cancel the insulin suspend feature. If patients fail to respond, the pump automatically suspends action for 2 hours, and then insulin therapy resumes.

The MiniMed® 630G System with SmartGuard™, which is similar to the 530G, includes updates to the system components including waterproofing.[9,] The threshold suspend feature can be programmed to temporarily suspend delivery of insulin for up to 2 hours when the sensor glucose value falls below a predefined threshold value. The MiniMed 630G System with SmartGuard™ is not intended to be used directly for making therapy adjustments, but rather to provide an indication of when a finger stick may be required. All therapy adjustments should be based on measurements obtained using a home glucose monitor and not on the values provided by the MiniMed 630G system. The device is not intended to be used directly for preventing or treating hypoglycemia but to suspend insulin delivery when the user is unable to respond to the SmartGuard™ Suspend on Low alarm to take measures to prevent or treat hypoglycemia themselves.

The MiniMed® 670G System is a hybrid closed-loop insulin delivery system consisting of an insulin pump, a glucose meter, and a transmitter, linked by a proprietary algorithm and the SmartGuard Hybrid Closed Loop.[10,] The system includes a low glucose suspend feature that suspends insulin delivery; this feature either suspends delivery on low-glucose levels or suspends delivery before low-glucose levels, and has an optional alarm (manual mode). Additionally, the system allows semiautomatic basal insulin-level adjustment (decrease or increase) to preset targets (automatic mode). As a hybrid system; basal insulin levels are automatically adjusted, but the patient needs to administer premeal insulin boluses. The continuous glucose monitoring component of the MiniMed 670G System is not intended to be used directly for making manual insulin therapy adjustments; rather it is to provide an indication of when a glucose measurement should be taken. The MiniMed 670G System was originally approved for marketing in the United States on September 28, 2016 (P160017), and received approval for marketing with a pediatric indication (ages 7-13 years) on June 21, 2018 (P160017/S031).

The MiniMed 770G System is an iteration of the MiniMed 670G System. In July 2020, the device was approved for use in children ages 2 to 6 years. In addition to the clinical studies that established the safety and effectiveness of the MiniMed 670G System in users ages 7 years and

older, the sponsor performed clinical studies of the 670G System in pediatric subjects ages 2 to 6 years. FDA concluded that these studies establish a reasonable assurance of the safety and effectiveness of the MiniMed 770G System because the underlying therapy in the 670G system, and the associated Guardian Sensor (3), are identical to that of the 770G System.[6,]

On June 21, 2018, the FDA approved the t:slim X2 Insulin Pump with Basal-IQ Technology (PMA P180008) for individuals who are 6 years of age and older.[11,] The System consists of the t:slim X2 Insulin Pump paired with the Dexcom G5 Mobile Continuous Glucose Monitoring, as well as the Basal-IQ Technology. The t:slim X2 Insulin Pump is intended for the subcutaneous delivery of insulin, at set and variable rates, for the management of diabetes mellitus in persons requiring insulin. The t:slim X2 Insulin Pump can be used solely for continuous insulin delivery and as part of the System as the receiver for a therapeutic continuous glucose monitoring. The t:slim X2 Insulin Pump running the Basal-IQ Technology can be used to suspend insulin delivery based on continuous glucose monitoring sensor readings.

In December 2019, FDA approved the t:slim X2 Insulin Pump with Control-IQ Technology through the De Novo process.[12,] The device uses the same pump hardware as the insulin pump component of the systems approved in t:slim X2 Insulin Pump with Basal-IQ Technology (P180008) and P140015. A custom disposable cartridge is motor-driven to deliver patient programmed basal rates and boluses through an infusion set into subcutaneous tissue.

POLICY

A. Use of an FDA-approved automated insulin delivery system (artificial pancreas device system) with a low glucose suspend feature may be considered **medically necessary** when **ALL** of the following criteria is met:

    1. In patients with type 1 diabetes who meet age requirement allowed by the FDA for the specific device prescribed (see Regulatory Status) **AND**

    2. Individual or caregiver must have completed a comprehensive education program within the past 12 months if they are a first time user of insulin pump therapy

B. Use of an automated insulin delivery system (artificial pancreas device system) not approved by the FDA is considered **experimental / investigational**.

C. All other indications for automated insulin delivery system (artificial pancreas device system) considered **not medically necessary**

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RATIONALE

The most recent literature update was performed through March 4, 2021.

Evidence reviews assess the clinical evidence to determine whether the use of a technology improves the net health outcome. Broadly defined, health outcomes are length of life, quality of life, and ability to function, including benefits and harms. Every clinical condition has specific outcomes that are important to patients and to managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of a technology, 2 domains are examined: the relevance and the quality and credibility. To be relevant, studies must represent 1 or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. Randomized controlled trials are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

This review was informed by a TEC Assessment (2013) on artificial pancreas device systems.[13,] This evidence review addresses artificial pancreas devices that have been approved by the U.S. Food and Drug Administration.

LOW-GLUCOSE SUSPEND DEVICES

Clinical Context and Therapy Purpose

The purpose of artificial pancreas device system with a low-glucose suspend feature in patients who have type 1 diabetes is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of an artificial pancreas device system with a low glucose suspend feature improve the net health outcome for individuals with type 1 diabetes?

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest is individuals with type 1 diabetes. Persons with type 1 diabetes are especially prone to develop hypoglycemia. Alterations in the counterregulatory hormonal responses inherent in the disease, variable patient adherence, and iatrogenic hypoglycemia caused by aggressive prevention of hyperglycemia are responsible for this propensity. Hypoglycemia affects many aspects of cognitive function, including attention, memory, and psychomotor and spatial ability. Severe hypoglycemia can cause serious morbidity affecting the central nervous system (e.g., coma, seizure, transient ischemic attack, stroke), heart (e.g., cardiac arrhythmia, myocardial ischemia, infarction), eye (e.g., vitreous hemorrhage, worsening of retinopathy), as well as cause hypothermia and accidents that may lead to injury. Fear of hypoglycemia symptoms can also cause decreased motivation to adhere strictly to intensive insulin treatment regimens.

Interventions

The therapy being considered is an artificial pancreas device system that integrates a continuous glucose monitor and insulin pump and includes a low glucose suspend feature that can automatically and temporarily suspend insulin delivery when glucose levels fall below a prespecified level. The device alarms and the user must take an action to assess glycemic level and resume insulin infusion.

Artificial pancreas device systems are used by persons with type 1 diabetes when they have experienced hyper glycemic and/or hypoglycemic episodes that cannot be managed with intermittent self-monitoring of glucose and self-administration of insulin. Artificial pancreas device system are used by persons with type 1 diabetes in "free-living" and home settings, with monitoring by primary care clinicians, diabetologists, and endocrinologists.

Comparators

The following therapies are currently being used to treat type 1 diabetes: nonintegrated continuous glucose monitoring plus insulin pump (open-loop) or self-monitoring blood glucose and multiple dose insulin therapy.

Outcomes

The general outcomes of interest are glycated hemoglobin A_{1c} (HbA_{1c}) levels, time in range or target of glucose levels, and rates of hypoglycemia and hyperglycemia. Other outcomes of interest include quality of life and changes in health care utilization (e.g., hospitalizations). The duration of follow-up is life-long.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

REVIEW OF EVIDENCE

Systematic Reviews

A TEC Assessment (2013) reviewed studies that reported on the use of artificial pancreas device systems in patients with type 1 or type 2 diabetes taking insulin who were 16 years and older.[13,]It included studies that compared an artificial pancreas device system containing a low glucose suspend feature with the best alternative treatment in the above population, had at least 15 patients per arm, and reported on hypoglycemic episodes. A single trial met the inclusion criteria, and the TEC Assessment indicated that, although the trial results were generally favorable, the study was flawed and further research was needed. Reviewers concluded that there was insufficient evidence to draw conclusions about the impact of an artificial pancreas device system, with a low glucose suspend feature, on health outcomes.

Randomized Controlled Trials

The single trial assessed in the TEC Assessment was the in-home arm of the Automation to Simulate Pancreatic Insulin Response (ASPIRE) trial, reported by Bergenstal et al (2013).[14,]This industry-sponsored trial used the Paradigm Veo insulin pump. A total of 247 patients were randomized to an experimental group, in which a continuous glucose monitor with the low glucose suspend feature was used (n=121), or a control group, which used the continuous glucose monitor but not the low glucose suspend feature (n=126). Key eligibility criteria were 16-to-70 years old, type 1 diabetes, and HbA_{1c}levels between 5.8% and 10.0%. In addition, patients had to have more than 6 months of experience with insulin pump therapy and at least 2 nocturnal hypoglycemic events (≤65 mg/dL) lasting more than 20 minutes during a 2-week run-in phase. The randomized intervention phase lasted 3 months. Patients in the low glucose suspend group were required to use the feature at least between 10 PM and 8AM. The threshold value was initially set at 70 mg/dL and could be adjusted to between 70 mg/dL and 90 mg/dL. Seven patients withdrew early from the trial; all 247 were included in the intention-to-treat analysis. The primary efficacy outcome was the area under the curve (AUC) for nocturnal hypoglycemia events. This was calculated by multiplying the magnitude (in milligrams per deciliter) and duration (in minutes) of each qualified hypoglycemic event. The primary safety outcome was change in HbA_{1c}levels.

The primary endpoint, mean (standard deviation [SD]) AUC for nocturnal hypoglycemic events, was 980 (1200) mg/dL/min in the low glucose suspend group and 1568 (1995) mg/dL/min in the control group. The difference between groups was statistically significant ($p<0.001$), favoring the intervention group.

Similarly, the mean AUC for combined daytime and nighttime hypoglycemic events (a secondary outcome) significantly favored the intervention group ($p<0.001$). Mean (SD) AUC values were 798 (965) mg/dL/min in the intervention group and 1164 (1590) mg/dL/min in the control group. Moreover, the intervention group experienced fewer hypoglycemic episodes (mean, 3.3 per patient-week; SD=2.0) than the control group (mean, 4.7 per patient-week; SD=2.7; $p<0.001$). For patients in the low glucose suspend group, the mean number of times the feature was triggered per patient was 2.08 per 24-hour period and 0.77 each night (10PM-8AM). The median duration of nighttime threshold suspend events was 11.9 minutes; 43% of events lasted for less than 5 minutes, and 19.6% lasted more than 2 hours. In both groups, the mean sensor glucose value at the beginning of nocturnal events was 62.6 mg/dL. After 4 hours, the mean value was 162.3 mg/dL in the low glucose suspend group and 140.0 mg/dL in the control group.

Regarding safety outcomes and adverse events, change in HbA_{1c} level was minimal, and there was no statistically significant difference between groups. Mean HbA_{1c} levels decreased from 7.26 to 7.24 mg/dL in the low glucose suspend group and from 7.21 to 7.14 mg/dL in the control group. During the study period, there were no severe hypoglycemic events in the low glucose suspend group and 4 events in the control group (range of nadir glucose sensor values in these events, 40-76 mg/dL). There were no deaths or serious device-related adverse events.

Before reporting on in-home findings, the ASPIRE researchers (Garget al [2012]) published data from the in-clinic arm of the study.[15,]This randomized crossover trial included 50 patients with type 1 diabetes who had at least 3 months of experience with an insulin pump system. After a 2-week run-in period to verify and optimize basal rates, patients underwent 2 in-clinic exercise sessions to induce hypoglycemia. The low glucose suspend feature on the insulin pump was turned on in 1 session and off in the other session, in random order. When on, the low glucose suspend feature was set to suspend insulin delivery for 2 hours when levels reached 70 mg/dL or less. The goal of the study was to evaluate whether the severity and duration of hypoglycemia were reduced when the low glucose suspend feature was used. The study protocol called for patients to start exercise with glucose levels between 100 mg/dL and 140 mg/dL and to use a treadmill or stationary bicycle until their plasma glucose levels were 85 mg/dL or less. The study outcome (duration of hypoglycemia) was defined as the period of time glucose values were lower than 70 mg/dL and above 50 mg/dL, and hypoglycemia severity was defined as the lowest observed glucose value. A successful session was defined as an observation period of 3 to 4 hours and with glucose levels above 50 mg/dL. Patients who did not attain success could repeat the experiment up to 3 times.

The 50 patients attempted 134 exercise sessions; 98 of them were successful. Duration of hypoglycemia was significantly shorter during the low glucose suspend on sessions (mean, 138.5 minutes; SD=68) than the low glucose suspend off sessions (mean, 170.7 minutes; SD=91; $p=0.006$). Hypoglycemia severity was significantly reduced in the low glucose suspend on group. The mean (SD) lowest glucose level was 59.5 (72) mg/dL in the low glucose suspend on group and 57.6 (5.7) mg/dL in the low glucose suspend off group ($p=0.015$). Potential limitations of the

Garg study included evaluation of the low glucose suspend feature in a research setting and short assessment period.

A second RCT evaluated the in-home use of the Paradigm Veo System.[16,]The trial by Lyet al (2013) in Australia was excluded from the 2013 TEC Assessment due to the inclusion of children and adults and lack of analyses stratified by age group (the artificial pancreas system approved in the United States at the time of the review was only intended for individuals ≥16 years). The Lyet trial included 95 patients with type 1 diabetes between 4 and 50 years of age (mean age, 18.6 years; >30% of sample <18 years old) who had used an insulin pump for at least 6 months. In addition, participants had to have an HbA_{1c} level of 8.5% or less and have impaired awareness of hypoglycemia (defined as a score of at least 4 on the modified Clarke questionnaire). Patients were randomized to 6 months of in-home use of the Paradigm Veo System with automated insulin suspension when the glucose sensor reached a preset threshold of 60 mg/dL or to continued use of an insulin pump without the low glucose suspend feature. The primary study outcome was the combined incidence of severe hypoglycemic events (defined as hypoglycemic seizure or coma) and moderate hypoglycemic events (defined as an event requiring assistance from another person). As noted, findings were not reported separately for children and adults.

The baseline rate of severe and moderate hypoglycemia was significantly higher in the low glucose suspend group (129.6 events per 100 patient-months) than in the pump-only group (20.7 events per 100 patient-months). After 6 months of treatment, and controlling for the baseline hypoglycemia rate, the incidence rate per 100 patient-months was 34.2 (95% confidence interval [CI], 22.0 to 53.3) in the pump-only group and 9.6 (95% CI, 5.2 to 17.4) in the low glucose suspend group. The incidence rate ratio was 3.6 (95% CI, 1.7 to 7.5), which was statistically significant favoring the low glucose suspend group. Although results were not reported separately for children and adults, the trialists conducted a sensitivity analysis in patients younger than 12 years (15 patients in each treatment group). The high baseline hypoglycemia rates could be explained in part by 2 outliers (children ages 9 and 10 years). When both children were excluded from the analysis, the primary outcome was no longer statistically significant. The incidence rate ratio for moderate and severe events excluding the 2 children was 1.7 (95% CI, 0.7 to 4.3). Mean HbA_{1c} levels (a secondary outcome) did not differ between groups at baseline or at 6 months. Change in HbA_{1c} levels during the treatment period was -0.06% (95% CI, -0.2%to 0.09%) in the pump-only group and -0.1% (95% CI,-0.3% to 0.03%) in the low glucose suspend group; the difference between groups was not statistically significant.

The Predictive Low-Glucose Suspend for Reduction Of LOw Glucose (PROLOG) Trial was a 6-week crossover RCT of the t:slim X2 pump with Basal-IQ integrated with a Dexcom G5 sensor and a predictive low glucose suspend algorithm compared to sensor-augmented pump therapy.[17,] Participants (N=103) were ages 6-72 years; 58% were less than 18 years old, 16% were 6 to 11 years old, 43% were 12 to 17 years old, and 42% were 18 years or older. The primary outcome was continuous glucose monitoring measured percentage of time <70 mg/dL in each 3-week period. Median time <70 mg/dL was reduced from 3.6% at baseline to 2.6% during the 3-week period in the predictive low glucose suspend system arm compared with 3.2% in the sensor augmented pump arm (difference [predictive low glucose suspend − sensor augmented pump] = −0.8%, 95% CI −1.1 to −0.5, p<0.001). There was 1 severe hypoglycemic event in the sensor augmented pump arm and none in the predictive low glucose suspend arm.

Retrospective Studies

Agrawal et al (2015) retrospectively analyzed use of the threshold suspend feature associated with the Paradigm Veo System in 20,973 patients, most of whom were treated outside of the United States.[18,]This noncontrolled descriptive analysis provided information on the safety of the device when used in a practice setting. The threshold suspend feature was enabled for 100% of the time by 14,673 (70%) patients, 0% of the time by 2249 (11%) patients, and the remainder used it intermittently. The mean (SD) setting used to trigger suspension of insulin was a sensor glucose level of 62.8 (5.8) mg/dL. On days when the threshold suspend feature was enabled, there was a mean of 0.82 suspend events per patient-day. Of these, 56% lasted for 0 to 5 minutes, and 10% lasted the full 2 hours. (Data on the length of the other 34% of events were not reported.) On days when the threshold suspend feature was on, sensor glucose values were 50 mg/dL or less 0.64% of the time compared with 2.1% of sensor glucose values 50 mg/dL or less on days when the feature was off. Reduction in hypoglycemia was greatest at night. Sensor glucose percentages equivalent to 17 minutes per night occurred when the threshold suspend feature was off versus glucose percentages equivalent to 5 minutes per night when the threshold suspend feature was on. Data on the use of the device has suggested fewer and shorter hypoglycemic episodes. The length and severity of hypoglycemic episodes were not fully discussed in this article.

Prospective Observational Studies

Gómez et al (2017) published the results of a cohort of 111 type 1 diabetic individuals with documented hypoglycemia and hypoglycemia unawareness who received a sensor-augmented insulin pump with low glucose suspend therapy.[19,]Participants used a combination system with the Medtronic Paradigm 722 or Paradigm Veo pump connected to the MiniMed continuous glucose monitoring device. At a mean follow-up of 47 months (SD=22.7), total daily insulin dose was reduced (mean difference, -0.22 U/kg; 95% CI, -0.18 to -0.26 U/kg; p<0.001). Hemoglobin A_{1c} levels were reduced from a baseline value of 8.8% (SD=1.9%) to 7.5% (SD=1.0%) at 5 months (mean difference, -1.3%; 95% CI, -1.09% to -1.50%; p<0.001) and 7.1% (SD=0.8%; mean difference, -1.7%; 95% CI, -1.59% to -1.90%; p<0.001). At baseline, 80% of subjects had had at least 1 episode of hypoglycemic awareness compared with 10.8% at last follow-up (p<0.001). Episodes of severe hypoglycemia decreased from 66.6% to 2.7% (p<0.001).

Section Summary: Low-Glucose Suspend Devices

For individuals who have type 1 diabetes who receive an artificial pancreas device system with a low-glucose suspend feature, the evidence includes 2 RCTs conducted in home settings. Relevant outcomes are symptoms, change in disease status, morbid events, resource utilization, and treatment-related morbidity. Primary eligibility criteria of the key RCT, the ASPIRE trial, were ages 16-to-70 years old, type 1 diabetes, glycated hemoglobin levels between 5.8% and 10.0%, and at least 2 nocturnal hypoglycemic events (≤65 mg/dL) lasting more than 20 minutes during a 2-week run-in phase. Both trials required at least 6 months of insulin pump use. Both RCTs reported significantly less hypoglycemia in the treatment group than in the control group. In both trials, primary outcomes were favorable for the group using an artificial pancreas system; however, findings from 1 trial were limited by nonstandard reporting of hypoglycemic episodes, and findings from the other trial were no longer statistically significant when 2 outliers (children) were excluded from analysis. The RCT limited to adults showed an improvement in the primary outcome (AUC for nocturnal hypoglycemic events). The AUC is not used for assessment in clinical practice but the current technology does allow user and provider review of similar trend data with continuous glucose monitoring.

Results from the ASPIRE study suggested that there were increased risks of hyperglycemia and potential diabetic ketoacidosis in subjects using the threshold suspend feature. This finding may be related to whether or not actions are taken by the user to assess glycemic status, etiology of the low glucose (activity, diet or medication), and to resume insulin infusion.

Both retrospective and prospective observational studies have reported reductions in rates and severity of hypoglycemic episodes in automated insulin delivery system users. The evidence is sufficient that the magnitude of reduction for hypoglycemic events in the type 1 diabetes population is likely to be clinically significant.

HYBRID CLOSED-LOOP INSULIN DELIVERY SYSTEMS

Clinical Context and Therapy Purpose

The purpose of a hybrid closed-loop insulin delivery system in patients who have type 1 diabetes is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The question addressed in this evidence review is: Does the use of a hybrid closed-loop insulin delivery system improve the net health outcome for individuals with type 1 diabetes?

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest is individuals with type 1 diabetes. Persons with type 1 diabetes are especially prone to develop hypoglycemia. Alterations in the counterregulatory hormonal responses inherent in the disease, variable patient adherence, and iatrogenic hypoglycemia caused by aggressive prevention of hyperglycemia are responsible for this propensity. Hypoglycemia affects many aspects of cognitive function, including attention, memory, and psychomotor and spatial ability. Severe hypoglycemia can cause serious morbidity affecting the central nervous system (e.g., coma, seizure, transient ischemic attack, stroke), heart (e.g., cardiac arrhythmia, myocardial ischemia, infarction), eye (e.g., vitreous hemorrhage, worsening of retinopathy), as well as cause hypothermia and accidents that may lead to injury. Fear of hypoglycemia symptoms can also cause decreased motivation to adhere strictly to intensive insulin treatment regimens.

Interventions

The therapy being considered is a hybrid closed-loop insulin delivery system. A hybrid closed-loop system continuously adjusts insulin delivery. However, at mealtime, the patient enters the number of carbohydrates being consumed in order for the insulin pump to determine the bolus meal dose of insulin.

Artificial pancreas device system are used by persons with Type 1 diabetes when they have experienced hyper glycemic and/or hypoglycemic episodes that cannot be managed with intermittent self-monitoring of glucose and self-administration of insulin. These devices are used in "free-living" and home settings, with monitoring by primary care clinicians, diabetologists, and endocrinologists.

Comparators

The following therapies are currently being used to treat type 1 diabetes: an automated insulin delivery system with low glucose suspend feature, nonintegrated continuous glucose monitoring plus insulin pump (open-loop), or self-monitoring blood glucose and multiple dose insulin therapy.

Outcomes

The general outcomes of interest are HbA_{1c} levels, time in range or target of glucose levels, and rates of hypoglycemia and hyperglycemia. Other outcomes of interest include quality of life and changes in health care utilization (e.g., hospitalizations). The duration of follow-up is life-long.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

REVIEW OF EVIDENCE

Prospective Studies

Bergenstalet al (2016) published a prospective single-arm study on the safety of the hybrid closed-loop system in patients with type 1 diabetes.[20,]It included 124 patients ages 14-to-75 years old who had type 1 diabetes for at least 2 years, HbA_{1c} levels less than 10.0%, and who had used an insulin pump for at least 6 months. There was an initial run-in period at baseline for patients to learn how to use the device followed by a 3-month period of device use. The study period included a 6-day hotel stay with a 1-day period of frequent sampling of venous blood glucose levels to verify device accuracy. The primary safety end points were the incidence of severe hypoglycemia and diabetic ketoacidosis and the incidence of device-related and serious adverse events.

There were no episodes of severe hypoglycemia or ketoacidosis during the study. A total of 28 device-related adverse events occurred, all of which could be resolved at home. There were 4 serious adverse events, 1 case each of appendicitis, bacterial arthritis, worsening rheumatoid arthritis, and *Clostridium difficile* diarrhea. There were also a number of predefined descriptive end points (but no statistically powered efficacy end points). The device was in the closed-loop mode for a median of 97% of the study period. Mean (SD) HbA_{1c} levels were 7.4% (0.9%) at baseline and 6.9% (0.6%) at the end of the study, and the percentage of sensor glucose values within the target range was 66.7% at baseline and 72.2% at the end of the study. A related study in children is ongoing (NCT02660827).

A multicenter pivotal trial published by Garget al (2017) evaluated the safety of Medtronic's hybrid closed-loop system, using methods similar to those of Bergenstal et al (2016), (NCT02463097) and employing the same device (MiniMed 670G).[21,] Of 129 subjects, 124 completed the trial; 30 were adolescents (age range, 14-21 years) and 94 were adults (age range, 22-75 years), all of whom had type 1 diabetes for at least 2 years before the study, and

used insulin pump therapy for 6 months or more. As with Bergenstal et al (2016), a 3-month study period was preceded by a run-in period for subjects to be more familiar with the equipment, and the sensor glucose values were confirmed by an extended hotel stay (6-day/5-night with daily exercise). In both the adolescent and adult cohorts, the trial found improvements during the study phase over the run-in phase, with an increased percentage of glucose values in the favorable range (for adults, a mean improvement of 68.8% to 73.8%; for adolescents, a mean improvement of 60.4% to 67.2%; $p<0.001$ for both cohorts). Similarly, the authors reported a decrease in the percentage of values outside of the target range (<70 mg/dL or >180 mg/dL): for adults, time spent below the target range decreased from 6.4% to 3.4% ($p<0.001$); time above the range decreased from 24.9% to 22.8% ($p=0.01$). For both cohorts, HbA_{1c} levels showed a significant reduction between baseline and the end of the study: for adults, the mean decreased from 7.3% to 6.8% ($p<0.001$), while for adolescents, the mean decreased from 7.7% to 7.1% ($p<0.001$). Secondary outcomes, which included a reduction of nocturnal hyperglycemia and hypoglycemia, increase in mean overall body weight, and a reduction of basal insulin, were favorable for the study phase, compared with the run-in phase; measurements from the hotel stay verified the in-home glucose values. However, there were several limitations in the trial, including its nonrandomized design, the exclusion of individuals who had recently experienced diabetic ketoacidosis or severe hypoglycemia, and the interaction between subjects and site personnel. Additionally, most of the adult cohort were already using continuous glucose monitoring, and baseline HbA_{1c} levels were lower than average for both cohorts; both baseline characteristics potentially limit the generalizability of the results.

One type of hybrid insulin delivery system employs a predictive algorithm to keep the patient's glucose levels within a specific range or zone, only increasing or decreasing insulin levels if the device detects that glucose levels are going to fall outside the defined zone. Forlenza et al (2017) published a randomized controlled crossover trial comparing the efficacy of a zone model predictive control algorithm with that of sensor-augmented pump therapy. The trial included 20 subjects (19 completed), all with type 1 diabetes and having at least 3 months treatment with a subcutaneous insulin infusion pump.[10,] The 6 -week, in-home study was divided into 2-week blocks, with 2 randomized groups alternating treatment between an artificial pancreas system (DiAs web monitoring) or sensor-augmented pump therapy (Dexcom Share); subjects in both arms reported glucose values and, if applicable, sensor failure. For several primary endpoints, which included percentage of time in the target glucose range (70-180 mg/dL) and reduction in hypoglycemia (<70 mg/dL), the algorithm-controlled artificial pancreas system was found to be superior to the sensor-augmented pump therapy (71.6 vs 65.2%, $p=0.008$; 1.3 vs 2%, $p= 0.001$, respectively). However, while the mean glucose value was lower in the artificial pancreas system than in the control group, the difference between them was not significant ($p=0.059$). Measurements of nocturnal hypoglycemia were consistent with day-to-day findings. For the secondary endpoint (safety of both systems after extended wear), the study found that the mean glucose did not change between the first and seventh day of wear. A limitation of the trial was its use of remote monitoring of subjects. Also, the trialists noted that given the marked difference in outcomes between responders and nonresponders, an error might have occurred in setting basal rates.

The remainder of the review is focused on additional studies that recently evaluated hybrid closed-loop systems in children and adolescents with type 1 diabetes. These studies are summarized in Tables 3 and 4.

The RCT by Tauschman, et al (2018) evaluated individuals with uncontrolled type 1 diabetes as reflected in mean Hb1c >8%. Approximately, 50% of the subjects were between 6-21 years of age and 25% were 6-12 years old.[22,] Both groups achieved a reduction in HbA_{1c} but the reduction was statistically greater in the hybrid closed loop group compared to the control group. The investigators reported that the HbA1c improvements were not different among children, adolescents, and adults (data not shown in tables). No severe hypoglycemic events were reported consistent with a decrease in time spent with glucose <70 mg/dl.

Abraham et al (2018) reported the results of a 6-month, multicenter, RCT in children and adolescents with type 1 diabetes comparing use of an insulin pump with suspend before low or predictive low-glucose management with sensor-augmented insulin pump therapy alone. At 6 months, significant reductions were seen in day and night hypoglycemia and number of hypoglycemic events <63 mg/dl lasting longer than 20 minutes. There were no differences in HbA_{1c} at 6 months in either group.

Forlenza et al (2019) reported the data and analysis of the supplemental information filed with the FDA to support the expanded indication for the MiniMed 670G system to children 7-13 years of age.[7,] The nonrandomized, single-arm, multicenter study reported the day and night use of the automated insulin delivery and predictive low glucose management for 3 months in the home setting. There were no serious adverse events and use of the system was associated with reduction in HbA_{1c} and increased time in target glucose range.

Wood et al (2018) reported an in-clinic evaluation of a 7 to 13-year-old cohort of the 670G pivotal trial that was designed to evaluate the performance characteristics of the device when activity induced hypoglycemic patterns were used to set individual device parameters for ongoing use by the study participant.[23,] The suspend before low prevention capability was confirmed in 97.5% of patients experiencing a sensor glucose of ≤55 mg/dl.

Messer et al (2018) reported on a subanalysis of the adolescent and young adult participants in the 670G pivotal trial to better characterize the carbohydrate input and insulin bolus determination features of the device over a 3-month period. Participants successfully utilized the device without significant changes in total daily dose of insulin but improved percentage time in range (70-180 mg/dl).

Breton et al (2020) reported results of a 16-week, open-label RCT comparing the t:slim X2 insulin pump with Control-IQ Technology to sensor-augmented pump therapy in 101 children with Type 1 diabetes ages 6 to 13 years.[24,] The glucose level was in the target range for a greater percentage of time with the use of the hybrid closed loop system than with the use of a sensor-augmented insulin pump. Improvements were sustained through 28 weeks in an uncontrolled extension study of 100 children who were enrolled in the RCT.[25,] Health-related quality of life and patient satisfaction measures from the RCT and the extension phase were reported by Cobry et al (2021).[26,] Neither children nor their parents in the hybrid closed loop group reported statistically significant changes in these outcomes compared with the sensor-augmented pump therapy group. The authors concluded that children receiving the hybrid closed loop system did not experience increased burden compared with those using sensor-augmented pump therapy.

No studies of a hybrid closed loop system in children under age 6 years have been published, but clinical study results for children ages 2-6 years are available in the FDA Summary of Safety and

Effectiveness for the MiniMed 670G System (Tables 3 and 4).[6,] This was a descriptive study to evaluate the safe use of the device's auto mode and was not designed to determine the effectiveness of the device compared to alternative treatments. Based on the pivotal study and an additional performance study submitted for the evaluation, FDA concluded with a reasonable assurance of effectiveness that the MiniMed 770G System can automatically adjust basal insulin rates based on continuous glucose monitoring values.

Table 3. Summary of Key Study Characteristics: Hybrid Closed-Loop in Children and Adolescents with Type 1 Diabetes

Study; Trial	Countries	Sites	Dates	Participants	Intervention Study Type	
				N Age Mean (SD)		
Tauschmann (2018)[22,] NCT02523131	UK, US	6	05/12/2016 - 11/17/2017	• 86 • >6 years • [6-12 years; n=23] • [13-21 years; n=19]	• MiniMe 640G[2] • HCL	RCT Intervention: • SAPT with PLGM (n=46) • Screening HbA1c %(SD) • 8.3 (0.6) Control: • SAPT alone (n=40) • Screening HbA1c %(SD) • 8.5 (0.5)
Abraham (2018)[27,]	Australia	5	8/2014 - NR	• 154 • 8-20 years • 13.2 (2.8)	• MiniMed 640G[2] • HCL	RCT Intervention: • SAPT with PLGM (n=80) Control: • SAPT alone (n=74)
Forlenza (2019)[15,] NCT02660827	US, Israel	9	4/18/2016 - 10/09/2017	• 105 • 7-13 years • 10.8 (1.8)	• MiniMed 670G[3] • HCL	Noncomparative pivotal trial
Wood (2018)[23,] NCT02660827	US, Israel	9	4/18/2016 - 10/09/2017	• 105 • 7-13 years • 10.8 (1.8)	• MiniMed 670G[3] • HCL	12-hour clinic evaluation of PLGM performance in

Study; Trial	Countries	Sites	Dates	Participants	Intervention Study Type	
						conjunction with exercise[4]
Messer (2018)[28], NCT02463097	US	3	2015 - 2018	• 31 • 14-26 • 17.8 (3.9)	• MiniMed 670G[3] • HCL	Sub-study of FDA pivotal trial for device: insulin delivery characteristics and time in range
FDA (2020)[6], Safety Evaluation of the Hybrid Closed Loop (HCL) System in Pediatric Subjects with Type 1 Diabetes (G150247)	US	7	2017-2018	• 46 • 2-6 years	• MiniMed 670G[3] • HCL	Noncomparative pivotal trial
Breton et l (2020)[24], NCT03844789	US	4	2019-2020	• 101 • 6-13 years	• t:slim X2 insulin pump with Control-IQ Technology[4] • HCL	RCT, open label Intervention: • HCL (n=78) Control: • SAPT (n=23)

FDA: U.S. Food and Drug Administration; HCL: hybrid closed loop; NR: not reported; PLGM: predictive low glucose management; PMA: premarket approval; RCT: randomized controlled trial; SAPT: sensor-augmented pump therapy; SD: standard deviation; T1D: type 1 diabetes.
[1]Data as submitted for FDA PMA Supplement P160017/S031.
[2]MiniMed 640G is hybrid closed loop device approved for use outside of US.
[3]MiniMed 670G is hybrid closed loop device approved for use in US.
[4]t:slim X2 insulin pump with Control-IQ Technology is hybrid closed loop device approved for use in US.
[5]Activity/exercise induced hypoglycemia protocol (walking, biking, playing Wii games, or other aerobic activities) intended to activate the "suspend before low" feature followed by evaluation up to 6 hours and at least 4 hours after insulin resumption.

Table 4. Summary of Key Study Results: Hybrid Closed-Loop in Children and Adolescents with Type 1 Diabetes

Study	Efficacy Outcomes			Safety Outcomes	
Tauschmann (2018)[22],					
Outcome Measure	*Group difference in time proportion in target glucose range (70-180md/dL) at 12 weeks Mean (SD)*		*HbA_{1c} % (SD) At 12 weeks*	*Hypoglycemia* A. *<63 mg/dl* B. *<50 mg/dl* *Percent time in given range (SD)*	

Study	**Efficacy Outcomes**			**Safety Outcomes**	
• SAPT with PLGM • SAPT alone • Difference • [95% CI] • P • SAPT with PLGM • SAPT alone • Difference • [95% CI] • P	• 68% (8) • 54% (9) • 10.8 • [8.2,13.5] • <0.0001		• 7.4 (0.6) • 7.7 (0.5) • -0.36 • [-0.53, -0.19] • <0.0001	A. • 1.4 (0.9, 1.9) • 2.0 (0.9,3.0) • -0.83 • [-1.4,-0.16] • 0.0130 B. • 0.3 (0.2, 0.6) • 0.5 (0.2, 0.9) • -0.09 • [-0.24, 0.01] • 0.08	
Abraham (2018)[27,]					
Outcome Measure	*Change in average percent time in hypoglycemia (SG <63 mg/dl) at 6 months*	*Change in average percent time in hypoglycemia (SG <54 mg/dl) at 6 months*	*HbA_{1c} Mean %(SD)*	*Hypoglycemic events (SG <63 mg/dl for >20 minutes) Events per patient-year*	*IAH^2(%)* • *Clarke score≥4* • *N =90 (≥12 years)*
SAPT with PLGM	• n=76 • 2.8% Δ1.4%	• n=76 • 1.3% Δ 0.6%	7.5(0.8) Δ 7.8(0.8)	139	4%
SAPT alone	• n=70 • 3% Δ2.6%	• n =70 • 1.4% Δ1.2%	7.4(0.7) Δ 7.6(1.0)	227	13%
Difference in LS means [95% CI] p	• -0.95% • [-1.30, -0.61] <0.0001	• -0.44% • [-0.64, -0.24] <0.0001	• 0.09 • [-0.10, 0.27] 0.35	• [221,234 vs 134,143] • <0.001	• -0.04 • [-0.52,0.43] 0.86
Forlenza (2019)[1] NCT02660827[15,]					
Outcome Measure	*HbA_{1c} Mean % (SD)*		*Time in Range (>70-180) Mean %(SD)*	*Hypoglycemia A. ≤70 mg/dl B. ≤54 mg/dl Mean %(SD)*	

Study	Efficacy Outcomes			Safety Outcomes	
Baseline Run-in phase (n=106) 3-month study phase (n=105) p	• 7.9 (0.8) • 7.5 (0.6) <0.001		• 65 (7.7) <0.001	A. ≤70 mg/dl • 4.7 (3.8) • 3.0 (1.6) <0.001 B. ≤54 mg/dl • 1.3 (1.5) • 0.8 (0.7) <0.001	
Wood (2018)[1](NCT0266087)[23],					
Outcome Measure	*N=79 participant activations of suspend before low Rate of "Suspend before Low" (%)*				
Reference range[3] • ≤55 mg/dl • ≤60 mg/dl • ≤65 mg/dl	• 77 (97.5) • 71 (89.9) • 63 (79.7)				
Messer (2018)[1](NCT02463097)[28],					
Outcome measure	*Mean percentage time in range (70-180 mg/dl) using HCL mode[4] Mean % (SD)*				
Days • Days 1-7 • Days 22-28 • Days 50-56 • Days 78-84	• 69.7 (10.6) • 69.5 (8.5) • 71.9 (8.1) • 71.5 (10.3)				
FDA (2020)[6],					

Study	Efficacy Outcomes			Safety Outcomes	
Safety Evaluation of the Hybrid Closed Loop (HCL) System in Pediatric Subjects with Type 1 Diabetes (G150247)					
Outcome measure	*Percent change from baseline in HbA1c Mean (SD); 95% CI*	*Total Daily Dose of insulin at end of study Mean (SD)*	*Time in range during study period, % Mean (SD); 95% CI*	*Adverse events*	
	-0.5 (0.7); -0.7, -0.3	16.1 U (4.7)	<50 mg/dL: 0.5 (0.4); 0.4 to 0.6 <54 mg/dL: 0.8 (0.6); 0.6 to 1.0 <60 mg/dL: 1.5 (0.9); 1.2 to 1.8 <70 mg/dL: 3.5 (1.6); 3.0 to 3.971 <180 mg/dL: 63.6 (9.4); 60.8 to 66.4 >180 mg/dL: 33.0 (9.9); 0.4 to 0.6 >250 mg/dL: 10.7 (5.9); 8.9 to 12.4 >300	• No reports of unanticipated serious adverse device effects, unanticipated non-serious adverse device/procedural effects • No reports of diabetic ketoacidosis events. • No reports of severe hypoglycemia events	

Study	Efficacy Outcomes			Safety Outcomes	
			mg/dL: 3.7 (2.9); 2.9 to 4.6 >350 mg/dL: 1.2 (1.1); 0.8 to 1.5		
Breton et l (2020)[24,] Cobry et al (2021)[26,] NCT03844789					
Outcome measure	Glycated hemoglobin level at 16 weeks		*Percent time in target range 70 to 180 mg/dL (Primary outcome)* *Mean (SD)*	*Adverse events*	
HCL	7.0 (0.8)		67 (10)	16 adverse events in 15 patients (19%) Median hypoglycemic events per week (IQR): 0.5 (0.1 to 0.8) Median hyperglycemic events per week (IQR): 3.0 (1.7 to 5.2) No severe hypoglycemia or diabetic ketoacidosis	
Control	7.6 (0.9)		55 (13)	3 adverse events in 2 patients (9%) Median hypoglycemic	

Study	Efficacy Outcomes			Safety Outcomes	
				events per week (IQR): 0.6 (0.1 to 1.0) Median hyperglycemic events per week (IQR): 5.6 (3.4 to 8.1) No severe hypoglycemia or diabetic ketoacidosis	
Between-group difference	-0.4 (95% CI, -0.9 to 0.1; p=0.08)		11% (7% to 14%); p<0.001	Median hypoglycemic events per week: p= 0.16 Median hyperglycemic events per week: p=0.001	

Δ: delta meaning change in status; CI: confidence interval; HbA1c; hemoglobin A1c; HCL: hybrid closed loop; IAH: impaired awareness of hypoglycemia; IQR: interquartile range; LS: least squares; PLGM: predictive low glucose management; SAPT: sensor-augmented pump therapy; SD: standard deviation; SG: sensor glucose; T1D: type 1 diabetes.
[1]Data as submitted for FDA PMA Supplement P160017/S031.
[2]Clarke score:uses 8 questions to characterize an individual's exposure to episodes of moderate and severe hypoglycemia to assess the glycemic threshold for and symptomatic response to hypoglycemia. A value ≥ 4 indicates IAH.
[3]Simultaneous testing with either intravenous sampling or self-monitoring blood glucometer.
[4]Open loop manual mode was used in a run-in phase to develop personalized parameters for HCL/Auto Mode phase.

Section Summary: Hybrid Closed-Loop Insulin Delivery Systems
For individuals who have type 1 diabetes who receive an artificial pancreas device system with a hybrid closed-loop insulin delivery system, the evidence includes multicenter pivotal trials using devices cleared by the Food and Drug Administration, supplemental data and analysis for expanded indications and more recent studies focused on children and adolescents. Three crossover RCTs using a similar first- generation device approved outside the United States have been reported. Relevant outcomes are symptoms, change in disease status, morbid events, resource utilization, and treatment-related morbidity. Of the 3 crossover RCTs assessing a related device conducted outside the United States, 2 found significantly better outcomes (i.e., time spent in nocturnal hypoglycemia and time spent in preferred glycemic range) with the device than with standard care and the other had mixed findings (significant difference in time spent in nocturnal hypoglycemia and no significant difference in time spent in preferred glycemic range).

For the U.S. regulatory registration pivotal trials, the primary outcomes were safety and not efficacy. Additional evidence from device performance studies and clinical studies all demonstrate

reductions in time spent in various levels of hypoglycemia, improved time in range (70-180 mg/dl), rare diabetic ketoacidosis, and few device-related adverse events. The evidence is sufficient that the magnitude of reduction for hypoglycemic events in the type 1 diabetes population is likely to be clinically significant.

Summary of Evidence

For individuals who have type 1 diabetes who receive an artificial pancreas device system with a low-glucose suspend feature, the evidence includes 2 randomized controlled trials (RCTs) conducted in home settings. Relevant outcomes are symptoms, change in disease status, morbid events, resource utilization, and treatment-related morbidity. Primary eligibility criteria of the key RCT, the Automation to Simulate Pancreatic Insulin Response (ASPIRE) trial, were ages 16-to-70 years old, type 1 diabetes, glycated hemoglobin levels between 5.8% and 10.0%, and at least 2 nocturnal hypoglycemic events (≤65 mg/dL) lasting more than 20 minutes during a 2-week run-in phase. Both trials required at least 6 months of insulin pump use. Both RCTs reported significantly less hypoglycemia in the treatment group than in the control group. In both trials, primary outcomes were favorable for the group using an artificial pancreas system; however, findings from 1 trial were limited by nonstandard reporting of hypoglycemic episodes, and findings from the other trial were no longer statistically significant when 2 outliers (children) were excluded from analysis. The RCT limited to adults showed an improvement in the primary outcome (area under the curve for nocturnal hypoglycemic events). The area under the curve is not used for assessment in clinical practice but the current technology does allow user and provider review of similar trend data with continuous glucose monitoring. Results from the ASPIRE study suggested that there were increased risks of hyperglycemia and potential diabetic ketoacidosis in subjects using the threshold suspend feature. This finding may be related to whether or not actions are taken by the user to assess glycemic status, etiology of the low glucose (activity, diet or medication), and to resume insulin infusion. Both retrospective and prospective observational studies have reported reductions in rates and severity of hypoglycemic episodes in automated insulin delivery system users. The evidence is sufficient that the magnitude of reduction for hypoglycemic events in the type 1 diabetes population is likely to be clinically significant. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have type 1 diabetes who receive an artificial pancreas device system with a hybrid closed-loop insulin delivery system, the evidence includes multicenter pivotal trials using devices cleared by the U.S. Food and Drug Administration, supplemental data and analysis for expanded indications, and more recent studies focused on children and adolescents. Three crossover RCTs using a similar first- generation device approved outside the United States have been reported. Relevant outcomes are symptoms, change in disease status, morbid events, resource utilization, and treatment-related morbidity. Of the 3 crossover RCTs assessing a related device conducted outside the United States, 2 found significantly better outcomes (i.e., time spent in nocturnal hypoglycemia and time spent in preferred glycemic range) with the device than with standard care and the other had mixed findings (significant difference in time spent in nocturnal hypoglycemia and no significant difference in time spent in preferred glycemic range). For the U.S. regulatory registration pivotal trial, the primary outcomes were safety and not efficacy. Additional evidence from device performance studies and clinical studies all demonstrate reductions in time spent in various levels of hypoglycemia, improved time in range (70-180 mg/dl), rare diabetic ketoacidosis, and few device-related adverse events. The evidence is sufficient that the magnitude of reduction for hypoglycemic events in the type 1 diabetes

population is likely to be clinically significant. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

SUPPLEMENTAL INFORMATION

The purpose of the following information is to provide reference material. Inclusion does not imply endorsement or alignment with the evidence review conclusions.

Clinical Input From Physician Specialty Societies and Academic Medical Centers

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

2019 Input

Clinical input supported that the outcome of hypoglycemia prevention provides a clinically meaningful improvement in net health outcome, and this use is consistent with generally accepted medical practice. Clinical input also supported that the use of hybrid closed loop artificial pancreas device systems provides a clinically meaningful improvement in net health outcome and is consistent with generally accepted medical practice. Reduction in the experience of hypoglycemia and inappropriate awareness of hypoglycemia and glycemic excursions were identified as important acute clinical outcomes in children, adolescents, and adults and are related to the future risk for end-organ complications.

Practice Guidelines and Position Statements

Guidelines or position statements will be considered for inclusion in 'Supplemental Information' if they were issued by, or jointly by, a US professional society, an international society with US representation, or National Institute for Health and Care Excellence (NICE). Priority will be given to guidelines that are informed by a systematic review, include strength of evidence ratings, and include a description of management of conflict of interest.

American Association of Clinical Endocrinologists et al

In 2018, the American Association of Clinical Endocrinologists and American College of Endocrinology published a joint position statement on the integration of insulin pumps and continuous glucose monitoring in patients with diabetes.[29,] The statement emphasized the use of continuous glucose monitoring and insulin pump therapy for type 1 diabetes patients who are not in glycemic target ranges despite intensive attempts at self-blood glucose monitoring and multiple insulin injection therapy.

American Diabetes Association

The American Diabetes Association has released multiple publications on controlling type 1 diabetes (Table 5).

Table 5. Recommendations on Diabetes

Date	Title	Publication Type	Recommendation (Level of Evidence)
2021	Standards of Medical Care in Diabetes	Guideline standard[18,]	Sensor-augmented pump therapy with automatic low glucose suspend may be considered for adults and youth with diabetes to prevent/mitigate episodes of hypoglycemia.(B) Automated insulin delivery systems may be considered in youth and adults with type 1 diabetes to improve glycemic control. (A) Individual patients may be using systems not approved by the U.S. Food and Drug Administration, such as do-it-yourself closed-loop systems and others; providers cannot prescribe these systems but should provide safety information/troubleshooting/backup advice for the individual devices to enhance patient safety. (E)
2017	Standardizing Clinically Meaningful Outcome Measures Beyond HbA1c for Type 1 Diabetes	Consensus report[30,],a	Developed definitions for hypoglycemia, hyperglycemia, time in range, and diabetic ketoacidosis in type 1 diabetes (NA)

HbA1c: hemoglobin A1c; N/A: not applicable.
a Jointly published with the American Association of Clinical Endocrinologists, the American Association of Diabetes Educators, the Endocrine Society, JDRF International, The Leona M. and Harry B. Helmsley Charitable Trust, the Pediatric Endocrine Society, and the T1D Exchange.

U.S. Preventive Services Task Force Recommendations

Not applicable.

Ongoing and Unpublished Clinical Trials

Some currently ongoing and unpublished trials that might influence this review are listed in Table 6.

Table 6. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
Ongoing			
NCT02748018[a]	Multi-center, Randomized, Parallel, Adaptive, Controlled Trial in Adult and Pediatric Patients With Type 1 Diabetes Using Hybrid Closed Loop System and Control (CSII, MDI, and SAP) at Home	1500	Dec 2021
NCT03739099	Assessment of the Efficacy of Closed-loop Insulin Therapy (Artificial Pancreas) on the Control of Type 1 Diabetes in Prepubertal Child in Free-life: Comparison Between Nocturnal	120	Sep 2021

NCT No.	Trial Name	Planned Enrollment	Completion Date
	and 24-hour Use on 18 Weeks, Followed by an Extension on 18 Weeks		
NCT04436796	The International Diabetes Closed Loop (iDCL) Trial: A Randomized Crossover Comparison of Adaptive Model Predictive Control (MPC) Artificial Pancreas Versus Sensor Augmented Pump (SAP)/Predictive Low Glucose Suspend (PLGS) in the Outpatient Setting in Type 1 Diabetes (DCLP4)	35	Sep 2021
NCT03774186	Pregnancy Intervention With a Closed-Loop System (PICLS) Study	47	Nov 2021
NCT04269668[a]	An Open-label, Two-center, Randomized, Cross-over Study to Evaluate the Safety and Efficacy of Glycemic Control Using Hybrid-closed Loop vs. Advanced Hybrid Closed-loop in Young Subjects With Type 1 Diabetes	28	Mar 2021
NCT03784027	An Open-label, Multi-centre, Multi-national, Randomized, 2-period Crossover Study to Assess the Efficacy, Safety and Utility of Closed Loop Insulin Delivery in Comparison With Sensor Augmented Pump Therapy Over 4 Months in Children With Type 1 Diabetes Aged 1 to 7 Years in the Home Setting With Extension to Evaluate the Efficacy of Home Use of Closed Loop Insulin Delivery.	81	Dec 2021

NCT: national clinical trial.
[a]Denotes industry-sponsored or cosponsored trial.

CODING

The following codes for treatment and procedures applicable to this policy are included below for informational purposes. This may not be a comprehensive list of procedure codes applicable to this policy.

Inclusion or exclusion of a procedure, diagnosis or device code(s) does not constitute or imply member coverage or provider reimbursement. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

The code(s) listed below are medically necessary ONLY if the procedure is performed according to the "Policy" section of this document.

CPT/HCPCS	
95249	Ambulatory continuous glucose monitoring of interstitial tissue fluid via a subcutaneous sensor for a minimum of 72 hours; patient-provided equipment, sensor placement, hook-up, calibration of monitor, patient training, and printout of recording
95250	Ambulatory continuous glucose monitoring of interstitial tissue fluid via a subcutaneous sensor for a minimum of 72 hours; physician or other qualified health care professional (office) provided equipment, sensor placement, hook-up, calibration of monitor, patient training, removal of sensor, and printout of recording
95251	Ambulatory continuous glucose monitoring of interstitial tissue fluid via a subcutaneous sensor for a minimum of 72 hours; analysis, interpretation and report
A4226	Supplies for maintenance of insulin infusion pump with dosage rate adjustment using therapeutic continuous glucose sensing, per week
E0787	External ambulatory infusion pump, insulin, dosage rate adjustment using therapeutic continuous glucose sensing
S1034	Artificial pancreas device system (e.g., low glucose suspend [LGS] feature) including continuous glucose monitor, blood glucose device, insulin pump and computer algorithm that communicates with all of the devices
S1035	Sensor; invasive (e.g., subcutaneous), disposable, for use with artificial pancreas device system
S1036	Transmitter; external, for use with artificial pancreas device system
S1037	Receiver (monitor); external, for use with artificial pancreas device system

ICD-10 DIAGNOSES	
E10.10-E13.9	Diabetes mellitus code range

REVISIONS	
03-06-2015	Policy added to the bcbsks.com web site.
02-03-2016	Updated Description section.

REVISIONS	
	Updated Rationale section.
	Updated References section.
10-01-2016	In Coding section: ▪ Added ICD-10 codes effective 10-01-2016: E13.37X1, E13.37X2, E13.37X3
01-18-2017	Updated Description section.
	Updated Rationale section.
	Updated References section.
01-01-2018	In Coding section: ▪ Added CPT code: 95249. ▪ Revised nomenclature to CPT codes: 95250, 95251. ▪ Removed ICD-9 codes.
03-01-2018	In Policy section: ▪ Added new Item C, "Use of hybrid closed loop insulin delivery system (including the Food and Drug Administration-approved device for age 14 and older) as an artificial pancreas device system is considered experimental / investigational."
	NOTE: The above revision was published to the bcbsks.com website on 01-30-2018; however, the revision was removed prior to medical policy implementation.
03-01-2018	Updated Description section.
	In Policy section: ▪ Removed previous Item A 2, "Type 1 diabetes" ▪ Removed previous Item A 4, "Used insulin pump therapy for more than 6 months" ▪ In current Item A 3 (previously Item A 5), removed "At least 2 documented nocturnal hypoglycemic events (see Policy Guidelines) in a 2 week period" and added "Hypoglycemic unawareness OR multiple documented episodes of nocturnal hypoglycemia (see Policy Guidelines)" ▪ Updated Policy Guidelines.
	Updated Rationale section.
	Updated References section.
11-07-2018	In Policy language: ▪ In Item A 1, "Age 16 and older" revised to read "Meets age requirement allowed by the FDA for the specific device prescribed (see Regulatory Status)."
	Updated References section.
01-04-2019	Updated Description section.
	Updated Rationale section.
	Remainder of policy reviewed; no revisions made.
05-21-2019	Updated Description section.
	In Policy section: ▪ In Item A, added "automated insulin delivery system" to read, "Use of an FDA-approved automated insulin delivery system (artificial pancreas device system) with a low glucose suspend feature may be considered medically necessary in patients with type 1 diabetes who meet ALL of the following criteria:" ▪ In Item B, added "automated insulin delivery system" and "individuals who do not meet the above criteria" and removed "all other situations" to read, "Use of an automated insulin delivery system (artificial pancreas device system) is considered experimental / investigational in individuals who do not meet the above criteria." ▪ Added new Item C, "Use of an automated insulin deliver system (artificial pancreas device system) not approved by the FDA is considered experimental / investigational."
	Updated Rationale section.
	Updated References section.

REVISIONS	
05-22-2020	Updated Description section.
	In Coding section: ▪ Added HCPCS Codes: A4226, E0787 (Eff 01-01-2020)
	Updated Rationale section.
	Updated Reference section.
06-03-2021	Updated Description section.
	In Policy section: In Item A: ▪ Removed "Difference approved 03-01-18" from A.1. ▪ Replaced "Glycated hemoglobin value between 5.8% and 10.1%" with "level < 10.0%" in Item A.2. ▪ Removed "Hypoglycemic unawareness OR multiple documented episodes of nocturnal hypoglycemia (see Policy Guidelines)." ▪ Added A.3 and A.4 Item B added to the policy Policy Guidelines removed from the policy
	Updated Rationale section.
	Updated Reference section.
06-01-2022	Updated Policy Section: ▪ Policy criteria changed to the following: A. Use of an FDA-approved automated insulin delivery system (artificial pancreas device system) with a low glucose suspend feature may be considered medically necessary when ALL of the following criteria is met: 1. In patients with type 1 diabetes who meet age requirement allowed by the FDA for the specific device prescribed (see Regulatory Status) AND 2. Individual or caregiver must have completed a comprehensive education program within the past 12 months if they are a first time user of insulin pump therapy B. Use of an automated insulin delivery system (artificial pancreas device system) not approved by the FDA is considered experimental / investigational. C. All other indications for automated insulin delivery system (artificial pancreas device system) considered not medically necessary
	Updated Coding Section ▪ Converted ICD-10 codes to range

REFERENCES

1. American Diabetes Association. 6. Glycemic Targets. Diabetes Care. Jan 2017; 40(Suppl 1): S48-S56. PMID 27979893
2. American Diabetes Association. 6. Glycemic Targets: Standards of Medical Care in Diabetes-2019. Diabetes Care. Jan 2019; 42(Suppl 1): S61-S70. PMID 30559232
3. Abraham MB, Jones TW, Naranjo D, et al. ISPAD Clinical Practice Consensus Guidelines 2018: Assessment and management of hypoglycemia in children and adolescents with diabetes. Pediatr Diabetes. Oct 2018; 19 Suppl 27: 178-192. PMID 29869358
4. Agiostratidou G, Anhalt H, Ball D, et al. Standardizing Clinically Meaningful Outcome Measures Beyond HbA 1c for Type 1 Diabetes: A Consensus Report of the American Association of Clinical Endocrinologists, the American Association of Diabetes Educators, the American Diabetes Association, the Endocrine Society, JDRF International, The Leona M. and Harry B. Helmsley Charitable Trust, the Pediatric Endocrine Society, and the T1D Exchange. Diabetes Care. Dec 2017; 40(12): 1622-1630. PMID 29162582

5. Food and Drug Administration (FDA). Guidance for Industry and Food and Drug Administration Staff: The Content of Investigational Device Exemption (IDE) and Premarket Approval (PMA) Applications for Artificial Pancreas Device Systems [draft]. 2012; https://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM259305.pdf. Accessed March 23, 2021
6. Food & Drug Administration. MiniMed 770G System. Summary of Safety and Effectiveness Data. 2020. https://www.accessdata.fda.gov/cdrh_docs/pdf16/P160017S076B.pdf. Accessed March 12, 2021.
7. Forlenza GP, Li Z, Buckingham BA, et al. Predictive Low-Glucose Suspend Reduces Hypoglycemia in Adults, Adolescents, and Children With Type 1 Diabetes in an At-Home Randomized Crossover Study: Results of the PROLOG Trial. Diabetes Care. Oct 2018; 41(10): 2155-2161. PMID 30089663
8. Food and Drug Administration (FDA). Premarket Approval (PMA): MiniMed 530G System. 2013; https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma.cfm?id=P120010. Accessed March 23, 2021
9. Food and Drug Administration (FDA). Premarket Approval (PMA): MiniMed 630G System with Smartguard. 2016; https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma.cfm?ID=320606. Accessed March 23, 2021
10. Food and Drug Administration (FDA). Premarket Approval (PMA): MiniMed 670G System. 2016; https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpma/pma.cfm?id=P160017. Accessed March 23, 2021.
11. Food and Drug Administration (FDA). t:slim X2 Insulin Pump with Basal-IQ Technology Premarket Approval (2018). https://www.accessdata.fda.gov/cdrh_docs/pdf18/P180008A.pdf. Accessed March 23, 2021.
12. Faulds ER, Zappe J, Dungan KM. REAL-WORLD IMPLICATIONS OF HYBRID CLOSE LOOP (HCL) INSULIN DELIVERY SYSTEM. Endocr Pract. May 2019; 25(5): 477-484. PMID 30865545
13. Blue Cross and Blue Shield Technology Evaluation Center (TEC). Artificial Pancreas Device Systems. TEC Assessments. 2013;Volume 28:Tab 14
14. Bergenstal RM, Garg S, Weinzimer SA, et al. Safety of a Hybrid Closed-Loop Insulin Delivery System in Patients With Type 1 Diabetes. JAMA. Oct 04 2016; 316(13): 1407-1408. PMID 27629148
15. Forlenza GP, Pinhas-Hamiel O, Liljenquist DR, et al. Safety Evaluation of the MiniMed 670G System in Children 7-13 Years of Age with Type 1 Diabetes. Diabetes Technol Ther. Jan 2019; 21(1): 11-19. PMID 30585770
16. Ly TT, Nicholas JA, Retterath A, et al. Effect of sensor-augmented insulin pump therapy and automated insulin suspension vs standard insulin pump therapy on hypoglycemia in patients with type 1 diabetes: a randomized clinical trial. JAMA. Sep 25 2013; 310(12): 1240-7. PMID 24065010
17. Forlenza GP, Ekhlaspour L, Breton M, et al. Successful At-Home Use of the Tandem Control-IQ Artificial Pancreas System in Young Children During a Randomized Controlled Trial. Diabetes Technol Ther. Apr 2019; 21(4): 159-169. PMID 30888835
18. American Diabetes Association. 7. Diabetes Technology: Standards of Medical Care in Diabetes-2021. Diabetes Care. Jan 2021; 44(Suppl 1): S85-S99. PMID 33298418
19. Garg SK, Weinzimer SA, Tamborlane WV, et al. Glucose Outcomes with the In-Home Use of a Hybrid Closed-Loop Insulin Delivery System in Adolescents and Adults with Type 1 Diabetes. Diabetes Technol Ther. Mar 2017; 19(3): 155-163. PMID 28134564

20. Beato-Vibora PI, Gallego-Gamero F, Lazaro-Martin L, et al. Prospective Analysis of the Impact of Commercialized Hybrid Closed-Loop System on Glycemic Control, Glycemic Variability, and Patient-Related Outcomes in Children and Adults: A Focus on Superiority Over Predictive Low-Glucose Suspend Technology. Diabetes Technol Ther. Dec 2020; 22(12): 912-919. PMID 31855446
21. Garg S, Brazg RL, Bailey TS, et al. Reduction in duration of hypoglycemia by automatic suspension of insulin delivery: the in-clinic ASPIRE study. Diabetes Technol Ther. Mar 2012; 14(3): 205-9. PMID 22316089
22. Tauschmann M, Thabit H, Bally L, et al. Closed-loop insulin delivery in suboptimally controlled type 1 diabetes: a multicentre, 12-week randomized trial. Lancet. Oct 13 2018; 392(10155): 1321-1329. PMID 30292578
23. Wood MA, Shulman DI, Forlenza GP, et al. In-Clinic Evaluation of the MiniMed 670G System Suspend Before Low Feature in Children with Type 1 Diabetes. Diabetes Technol Ther. Nov 2018; 20(11): 731-737. PMID 30299976
24. Breton MD, Kanapka LG, Beck RW, et al. A Randomized Trial of Closed-Loop Control in Children with Type 1 Diabetes. N Engl J Med. Aug 27 2020; 383(9): 836-845. PMID 32846062
25. Kanapka LG, Wadwa RP, Breton MD, et al. Extended Use of the Control-IQ Closed-Loop Control System in Children With Type 1 Diabetes. Diabetes Care. Feb 2021; 44(2): 473-478. PMID 33355258
26. Cobry EC, Kanapka LG, Cengiz E, et al. Health-Related Quality of Life and Treatment Satisfaction in Parents and Children with Type 1 Diabetes Using Closed-Loop Control. Diabetes Technol Ther. Jan 28 2021. PMID 33404325
27. Abraham MB, Nicholas JA, Smith GJ, et al. Reduction in Hypoglycemia With the Predictive Low-Glucose Management System: A Long-term Randomized Controlled Trial in Adolescents With Type 1 Diabetes. Diabetes Care. Feb 2018; 41(2): 303-310. PMID 29191844
28. Messer LH, Forlenza GP, Sherr JL, et al. Optimizing Hybrid Closed-Loop Therapy in Adolescents and Emerging Adults Using the MiniMed 670G System. Diabetes Care. Apr 2018; 41(4): 789-796. PMID 29444895
29. Gomez AM, Marin Carrillo LF, Munoz Velandia OM, et al. Long-Term Efficacy and Safety of Sensor Augmented Insulin Pump Therapy with Low-Glucose Suspend Feature in Patients with Type 1 Diabetes. Diabetes Technol Ther. Feb 2017; 19(2): 109-114. PMID 28001445
30. Brown SA, Kovatchev BP, Raghinaru D, et al. Six-Month Randomized, Multicenter Trial of Closed-Loop Control in Type 1 Diabetes. N Engl J Med. Oct 31 2019; 381(18): 1707-1717. PMID 31618560

OTHER REFERENCES

1. Blue Cross Blue Shield of Kansas Pediatric Liaison Committee, July 2015; July 2018; January 2019, July 2021, January 2022.
2. Blue Cross Blue Shield of Kansas Internal Medicine Liaison Committee, August 2015; August 2018, August 2021, February 2022.