



Automated Insulin Delivery Systems: Behaviors for Success

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Disclosures

- No disclosures to report

Objectives

- Outline currently available automated insulin delivery (AID) systems and briefly review relevant features
- Explain benefits of AID systems in diabetes management
- Discuss behaviors and diabetes management modifications that may improve time in range and overall diabetes outcomes when using an AID system

Important!

- Throughout the talk I will refer to automated insulin delivery systems (AID). These can also be called hybrid closed-loop (HCL) systems.
- This information is current (to my knowledge) as of March 2024. Diabetes technology is rapidly changing the information contained in this presentation may outdate quickly.
- As always, diabetes management is individualized. Not all strategies or concepts are feasible for all children.

Sensor Augmented Pump Therapy

- Pump displays sensor data
- Delivers programmed basal rate *without* adjustment based on sensor glucose

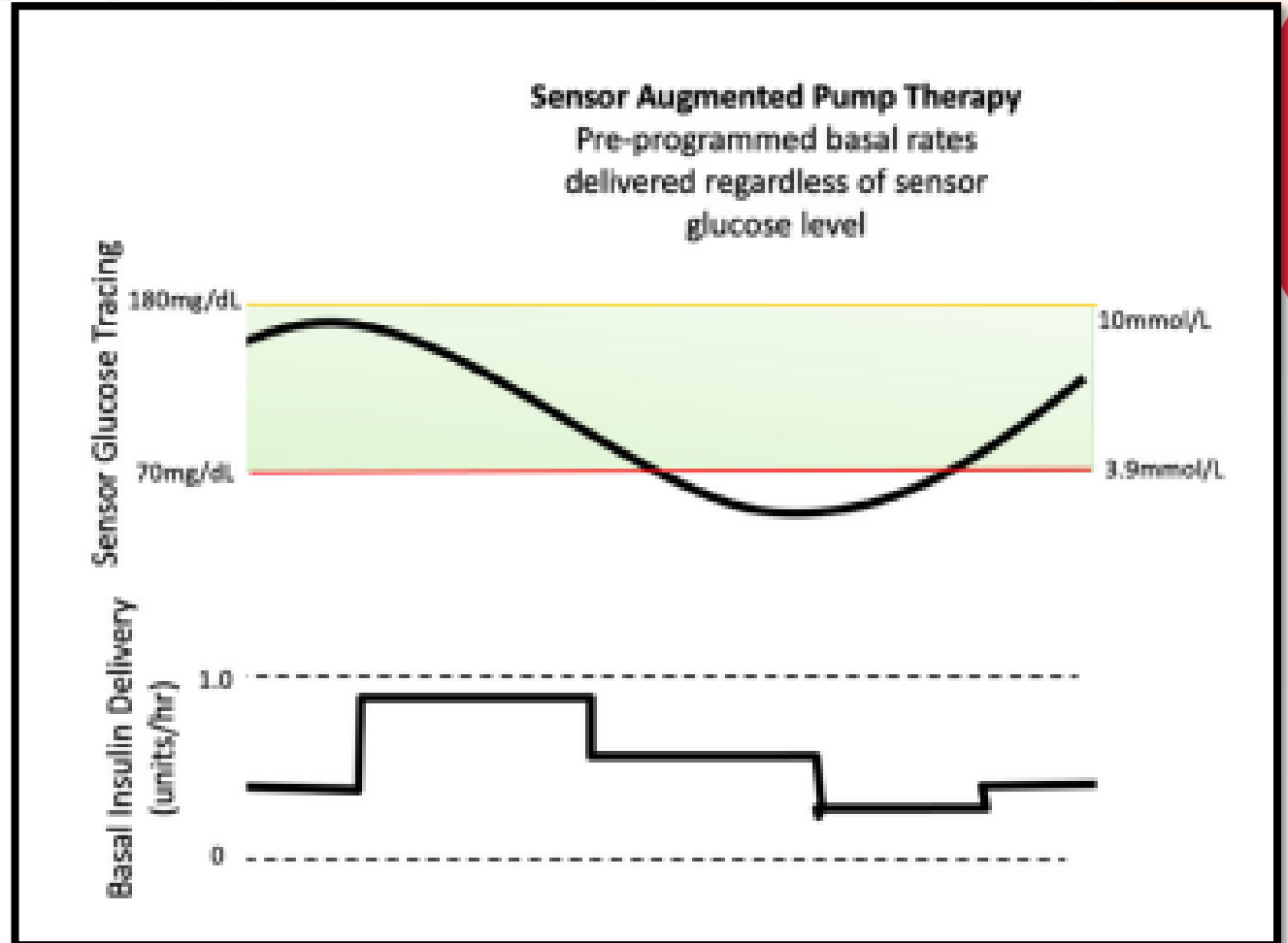


Image from Sherr et al., 2022 in ISPAD Clinical Practice Consensus Guidelines, Chapter 17: Insulin Delivery

Low Glucose Suspend

- Pump suspends basal delivery once glucose is *at or below* the low threshold

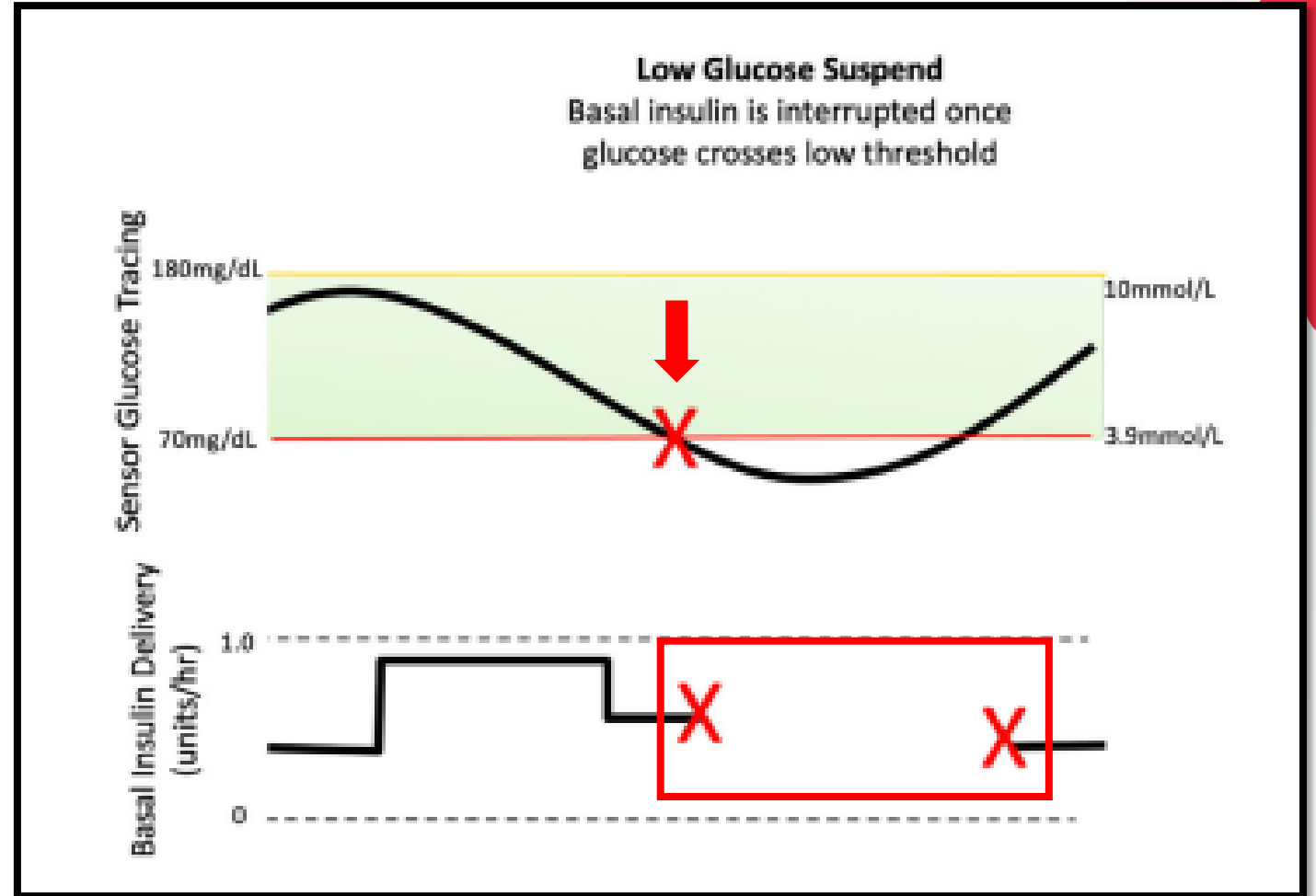


Image from Sherr et al., 2022 in ISPAD Clinical Practice Consensus Guidelines, Chapter 17: Insulin Delivery

Predictive Low Glucose Suspend

- Pump uses CGM data to predict low blood sugar and suspends insulin delivery *prior to* low glucose

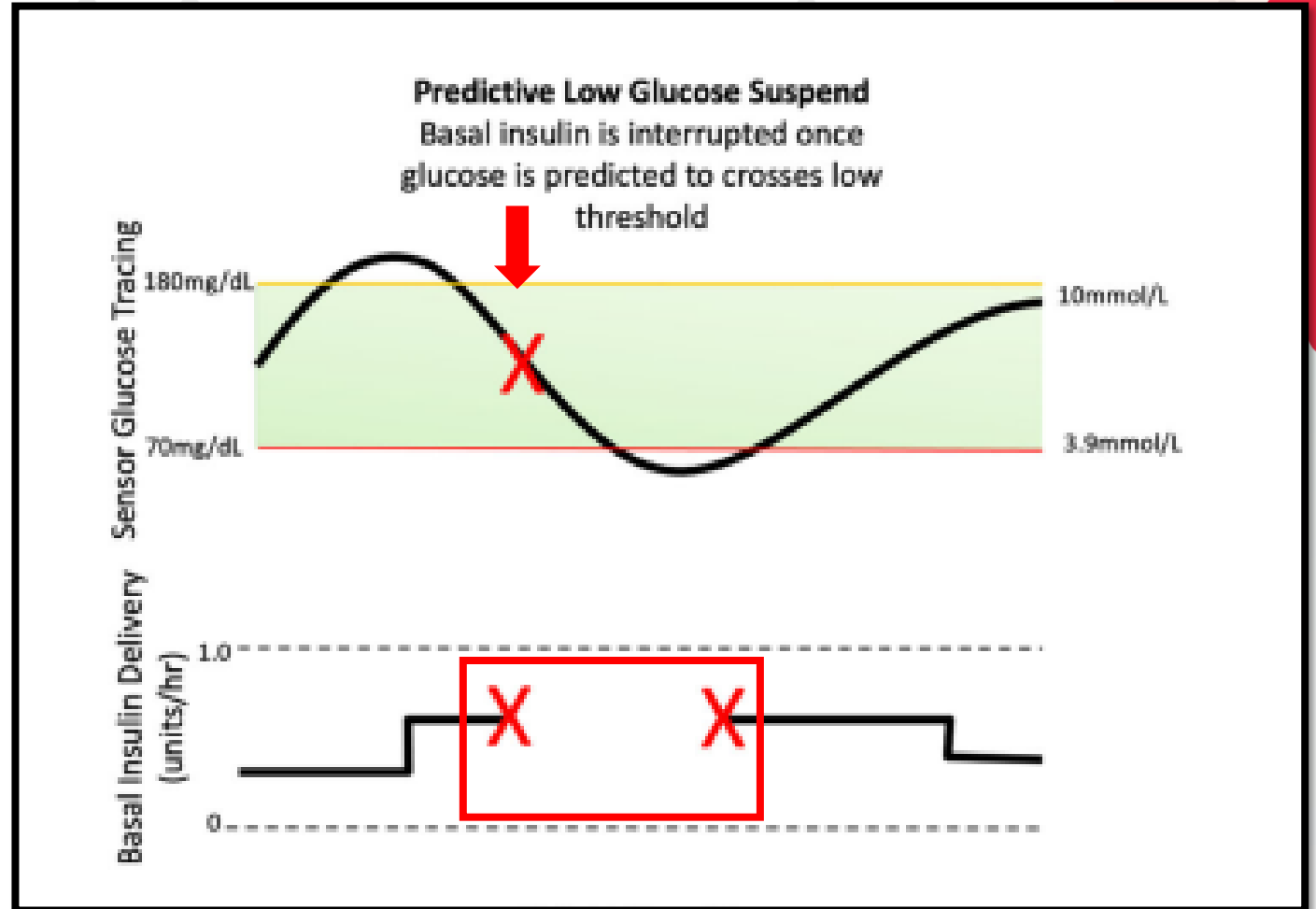


Image from Sherr et al., 2022 in ISPAD Clinical Practice Consensus Guidelines, Chapter 17: Insulin Delivery

Hybrid Closed Loop Systems

- Sensor glucose is used to adjust basal insulin delivery
- Users must enter carbs/announce meals

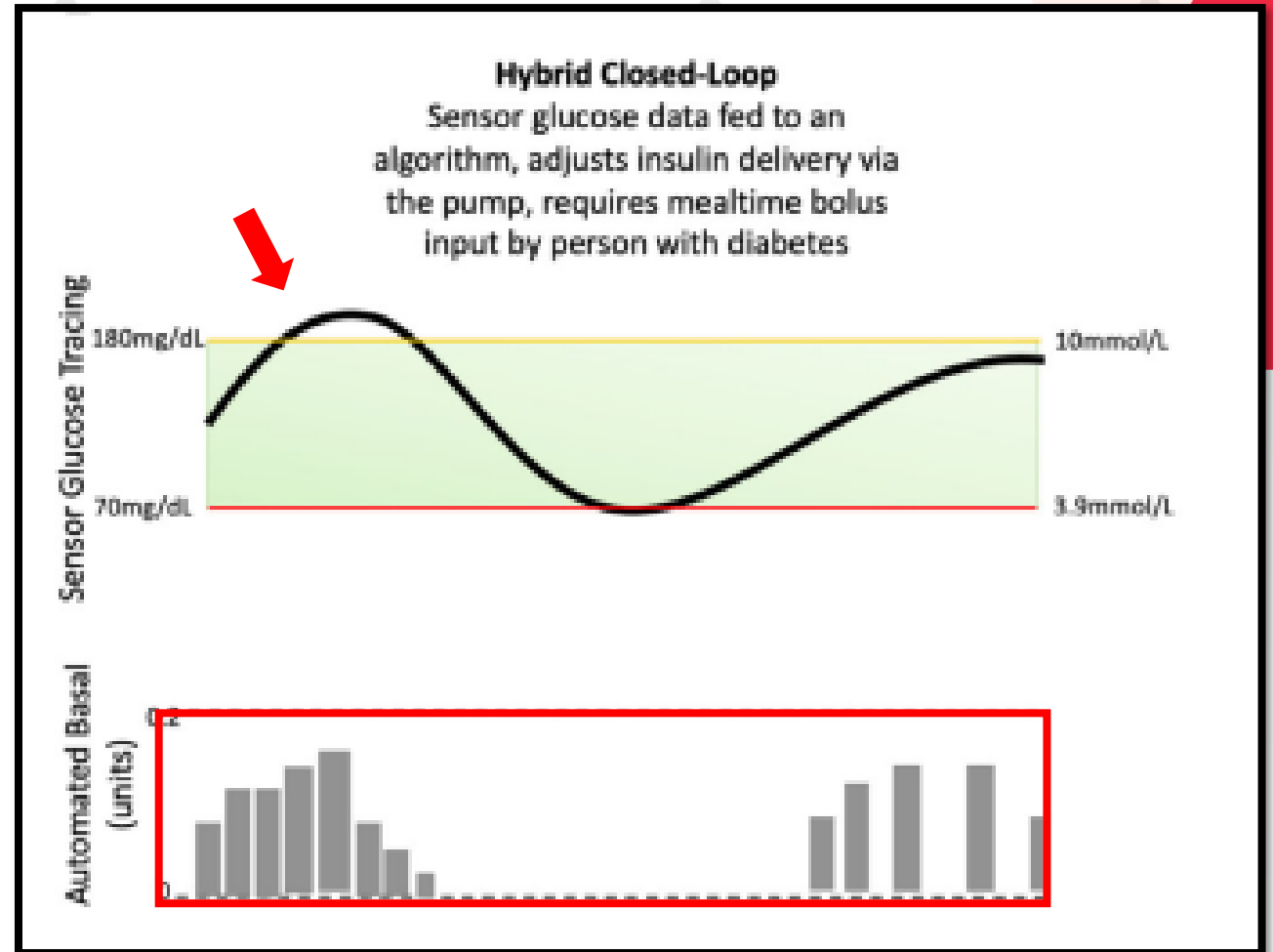


Image from Sherr et al., 2022 in ISPAD Clinical Practice Consensus Guidelines, Chapter 17: Insulin Delivery

What is an Automated Insulin Delivery (AID) System?

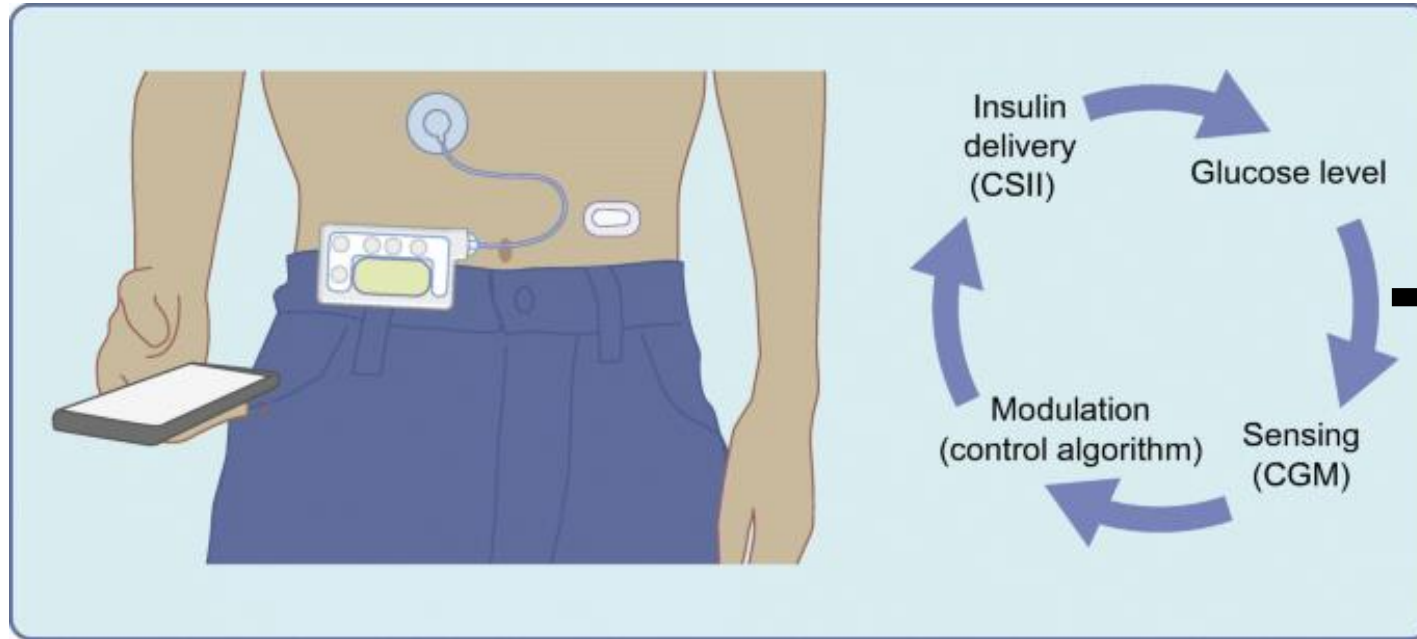


Image: Boughton & Hovorka, Diabetologia, 2021

Insulin Pump with an **Automated Delivery Algorithm** and **Compatible CGM**

Glucose values and trends from CGM are processed through the software in the insulin pump to drive insulin delivery.

Recommendations

International Society of Pediatric and Adolescent Diabetes (ISPAD) and the 2024 ADA guidelines recommend offering AID Systems to children with diabetes.

AID systems may **improve time in range (TIR)** by minimizing high and low blood sugars and are especially beneficial in attaining blood sugars in the target range overnight. AID systems **may reduce the burden of diabetes management** in some patients.

Commercially Available AID Systems



Image: Medtronic.com



Image: Tandemdiabetes.com



Image: ADA Consumer Guide



Image: ADA Consumer Guide

For additional information on specific pump features:
<https://www.pantherprogram.org/device-comparison-chart>

Medtronic

	770G	780G
Automated Basal Adjustment	✓	✓
	Adjusts basal rate every 5 min to target setting. Calculated from Total daily insulin, updated every day at Midnight. Uses last 6 days of CGM data to determine dosing.	
Automated Correction Boluses	✗	✓
		Determined by pump (not user programmed setting) up to every 5 min if glucose >120 mg/dL.
Strategy for Carb Intake	User should bolus for carbohydrate grams consumed using bolus calculator. 780G offers “Meal Detection,” increased dosing to help with rapid-rises in glucose related to meal intake when user doesn’t bolus	
Target	120 mg/dL (not adjustable)	100, 110, or 120 mg/dL
CGM Compatibility	Medtronic Guardian 3	Medtronic Guardian 3 or Guardian 4
Mobile App	Minimed Mobile App for compatible phones. User can get alerts and alarms, share data. No bolus from phone feature.	



Image: Medtronic.com

- [User Manual](#)
- [Virtual Pump Demo](#)
- School Nurse Guide Available from Rep
- [School Nurse Webinar](#)
- [Panther Sheet for 670 and 770G users](#)

Tandem Control IQ

Automated Basal Adjustment	✓
	Starts from programmed basal setting in pump. Adjusts every 5 min based on 30 min prediction of glucose levels.
Automated Correction Boluses	✓
	60% of programmed correction up to every 60 min. Targets 110 mg/dL.
Strategy for Carb Intake	User should bolus for carbohydrate grams consumed using bolus calculator.
Target	112.5 -160 mg/dL Exercise Mode 140-160 mg/dL Sleep Activity 112.5-120 mg/dL <i>These targets are fixed.</i>
CGM Compatibility	Dexcom G6, G7, and Freestyle Libre 2 Plus Mobi: G6 only (for now)
Mobile App	t:connect mobile app with compatible phones. Users can BOLUS from phone. Can view messages and alerts (clear alerts on pump only).
Notes	Automated corrections still given in exercise mode, not in sleep mode.

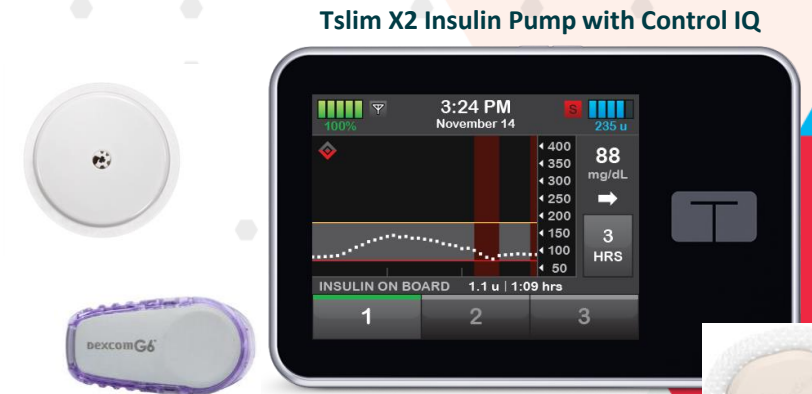


Image: Tandemdiabetes.com

Mobi with Control IQ



- [User Manual Tslim X2 with CIQ](#)
- [User Manual Mobi](#)
- [Virtual Pump Demo](#)
- [Panther Sheet](#)

Tandem Control IQ

- Mobi
 - Same CIQ Algorithm as used in Tslim X2 pump
 - New, Smaller footprint, uses 5" tubing
 - Can clip to pants or place in adhesive sleeve
 - Controlled by app on compatible phone (MUST have access to phone!)
 - Button on pump (*see pic at right*) that can bolus in "units" or "carbs" based on programmed setting



Images:
Tandemdiabetes.com



Kids

 School of Medicine
and Public Health
UNIVERSITY OF WISCONSIN-MADISON

Tandem T-Simulator App



Omnipod 5

Automated Basal Adjustment	✓
	Adaptive basal adjustments every 5 min based on 60 min prediction of CGM glucose. Calculated from total daily insulin dose, updated every pod change.
Automated Correction Boluses	✗
Strategy for Carb Intake	User should bolus for carbohydrate grams consumed using bolus calculator.
Target	5 options: 110, 120, 130, 140, 150 mg/dL <i>Up to 8 settings per 24 hour period.</i>
CGM Compatibility	Dexcom G6
Mobile App	Omnipod 5 App for compatible Android Phones allow full pump control (including boluses). iPhone compatibility expected 2024.
Notes	Pod and CGM can communicate and continue to adjust basal when away from phone/controller. Phone/Controller required to initiate bolus, get alerts and alarms, etc <i>*Omnipod is not covered by WI Medicaid</i>



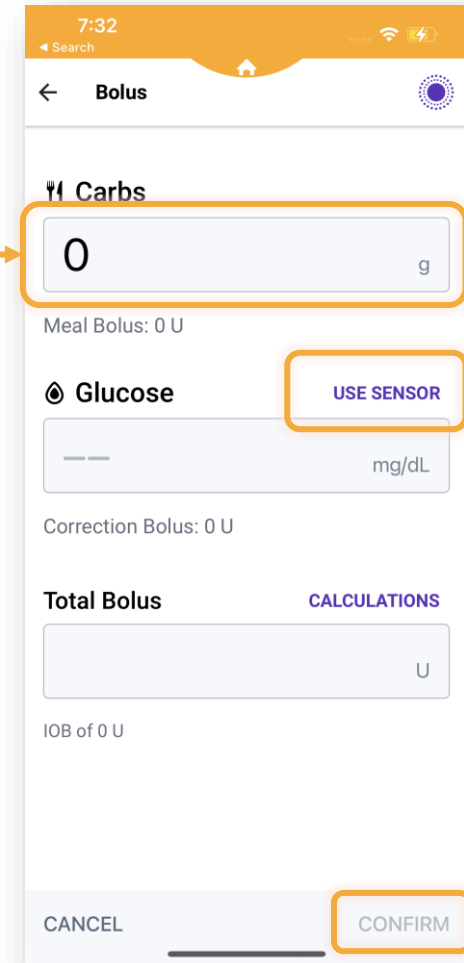
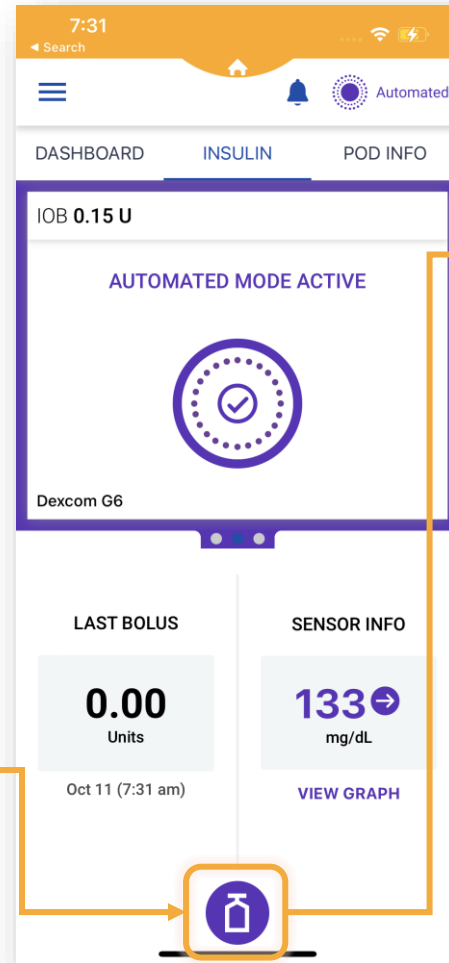
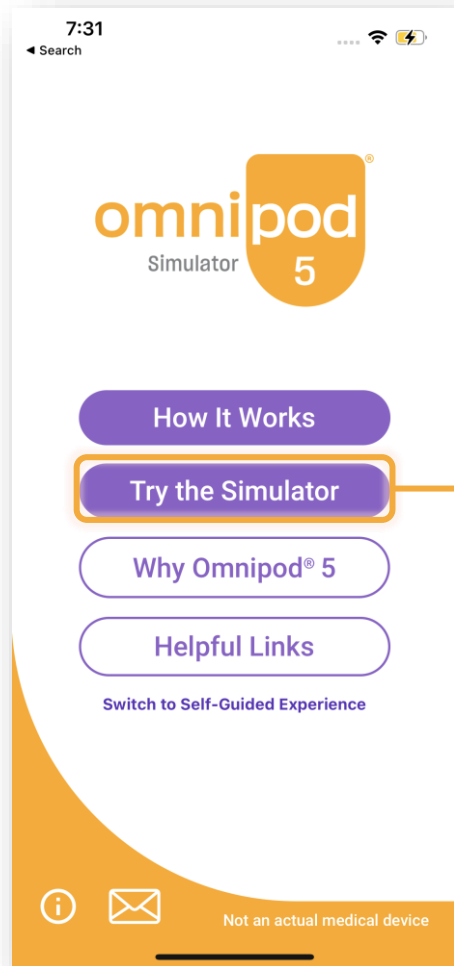
Image: ADA Consumer Guide

- [User Guide](#)
 - [Caregiver Guide](#)
 - [Simulator App](#)
 - [Panther Sheet](#)
 - [School Nurse Guide](#)
- PDF:



Adobe Acrobat
Document

Omnipod5® Simulator



Beta Bionics iLet Bionic Pancreas

Automated Basal Adjustment	<p style="text-align: center;">✓</p> <p>Adjusts basal rate every 5 min based on glucose profile over the last 24 hours, current CGM reading, and glucose trend.</p>
Automated Correction Boluses	<p style="text-align: center;">✓</p> <p>Provided above the basal rate (as required) every 5 min based on the glucose profile over last 24 hours, CGM trend, and insulin on board.</p>
Strategy for Carb Intake	<p>User announces meal based on mealtime (breakfast, lunch, and dinner) and carbohydrate content. User selects “usual”, “less” (~50% of usual), or “more” (~150% of usual)</p>
Target	<p>Usual (120 mg/dL), Lower (110 mg/dL), Higher (130 mg/dL)</p>
CGM Compatibility	<p>Dexcom G6 and G7</p>
Mobile App	<p>iLet mobile app allows users to share data to Beta Bionics portal and obtain software updates. Cannot adjust pump or bolus from phone.</p>
Notes	<p>Initiate with WEIGHT and Target setting. No ability to command other boluses. No traditional pump settings, activity mode, or manual mode. Can run for 48-72 hours without CGM and then user must switch to injections.</p>

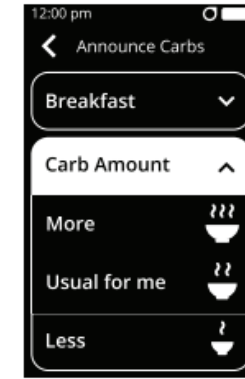
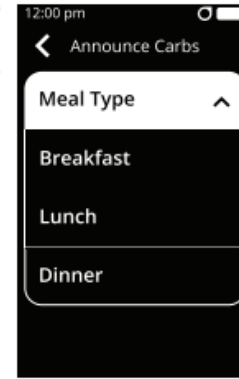


Image: ADA Consumer Guide

Image: iLet User Guide

Carb Amount	Example	
Usual for me Carb Amount		This is the usual amount of carbs you would typically eat for that meal type.
More Carb Amount		This is around 50% more carbs than your Usual for me meal (1.5 times as many carbs as your Usual for me meal).
Less Carb Amount		This is around half as many carbs than your Usual for me meal (50% of your Usual for me meal).
DO NOT ANNOUNCE		If the meal or snack you are eating has less than one quarter (25%) of the carbs in your Usual for me meal, you do not need to announce.

Imagez: iLet User Guide

- [User Guide](#)
- [Virtual Pump Demo](#)
- [Panther Sheet](#)

DIY AID Systems

- Non-FDA Approved AID Systems
 - Lack of regulatory oversight means innovations are typically available earlier than they are on commercial systems
- Use a compatible insulin pump and CGM with a control algorithm sourced from an online community to deliver insulin
- Labor intensive build/maintenance
- Users often report high level of satisfaction

Coming...Soon?










- Twiist Insulin Delivery Device and Tidepool Loop Algorithm
FDA approval announced March 18, 2024.



Image: Fiercebiotech.com

	770G	780G	CIQ	OP5	iLet
Automated Basal Adjustment					
	Adjusts basal rate every 5 min to target setting. Calculated from Total daily insulin, updated daily at Midnight. Uses last 6 days of CGM data to determine dosing.		Starts from programmed basal setting in pump. Adjusts every 5 min based on 30 min prediction of glucose levels.	Adaptive basal adjustments every 5 min based on 60 min prediction of CGM glucose. Calculated from total daily insulin dose, updated every pod change.	Adjusts basal rate every 5 min based on glucose profile over the last 24 hours, current CGM reading, and glucose trend.
Automated Correction Boluses					
		Up to every 5 min if glucose >120 mg/dL	60% of programmed correction up to every 60 min. Targets 110 mg/dL.		Provided above the basal rate (as required) every 5 min based on the glucose profile over last 24 hours, CGM trend, and insulin on board.
Strategy for Carb Intake	User should bolus for carbohydrate grams consumed using bolus calculator. 780G offers “Meal Detection,” increased dosing to help with rapid-rises in glucose related to meal intake when user doesn’t bolus		User should bolus for carbohydrate grams consumed using bolus calculator.	User should bolus for carbohydrate grams consumed using bolus calculator.	User announces meal based on mealtime (breakfast, lunch, and dinner) and carbohydrate content. User selects “usual”, “less” (~50% of usual), or “more” (~150% of usual)
Target	120 mg/dL (not adjustable)	100, 110, or 120 mg/dL (basal rate targets this)	112.5 -160 mg/dL Exercise Mode 140-160 mg/dL Sleep Activity 112.5-120 mg/dL <i>These targets are fixed.</i>	5 options: 110, 120, 130, 140, 150 mg/dL <i>Up to 8 settings per 24-hour period.</i>	Usual (120 mg/dL), Lower (110 mg/dL), Higher (130 mg/dL)
CGM Compatibility	Medtronic Guardian 3	Medtronic Guardian 3 or Guardian 4	Dexcom G6, G7, and Freestyle Libre 2 Plus Mobi: G6 only (for now)	Dexcom G6	Dexcom G6 and G7
Mobile App	Minimed mobile app for compatible phones. User can get alerts and alarms, share data. No bolus from phone feature.		t:connect mobile app with compatible phones. Users can BOLUS from phone. Can view messages and alerts (clear alerts on pump only). Mobi users must use app.	Omnipod 5 App for compatible Android Phones allow full pump control (including boluses). iPhone compatibility expected 2024.	iLet mobile app allows users to share data to Beta Bionics portl and obtain software updates. Cannot adjust pump or bolus from phone.
Notes			Automated corrections still given in exercise mode, not in sleep mode.	Pod and CGM can communicate and continue to adjust basal when away from phone/controller. Phone/Controller required to initiate bolus, get alerts and alarms, etc <i>*Omnipod is not covered by WI Medicaid</i>	Initiate with WEIGHT and Target setting. No ability to command other boluses. No traditional pump settings, activity mode, or manual mode. Can run for 48-72 hours without CGM and then user must switch to injections.

CGM Integration

					
Dexcom G6 	✗	✓	✓	✓	✓
Dexcom G7 	✗	✓ 	Expected in 2024	✓	Expected in 2024
Libre 2 Plus 	✗	✓ 	Expected in 2024- May be Libre 3?	✗	✗
Medtronic Guardian 4 	✓	✗	✗	✗	✗

Managing Expectations

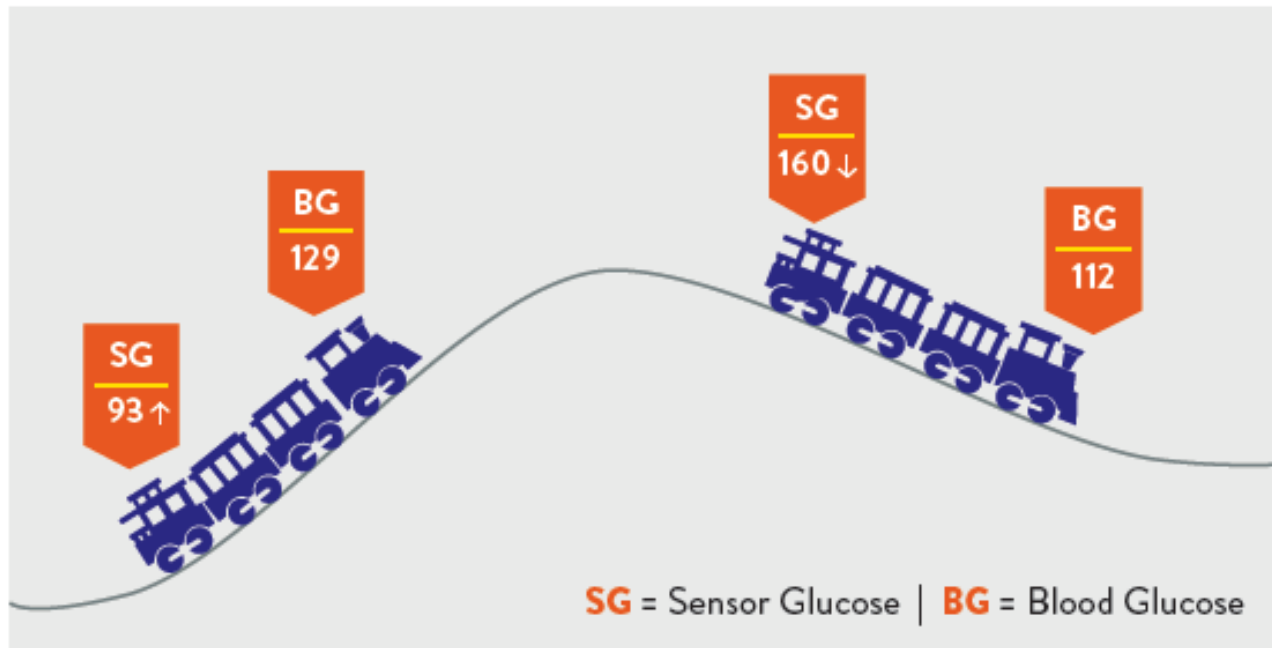
- AID systems are helpful tools that can improve diabetes related outcomes.
- They do not eliminate the **work/burden** of diabetes and require high level of user oversight and engagement for success.
- It may take time to learn the system and how to use it most effectively.
- Users will still have high and low blood sugars.



Behaviors for Success

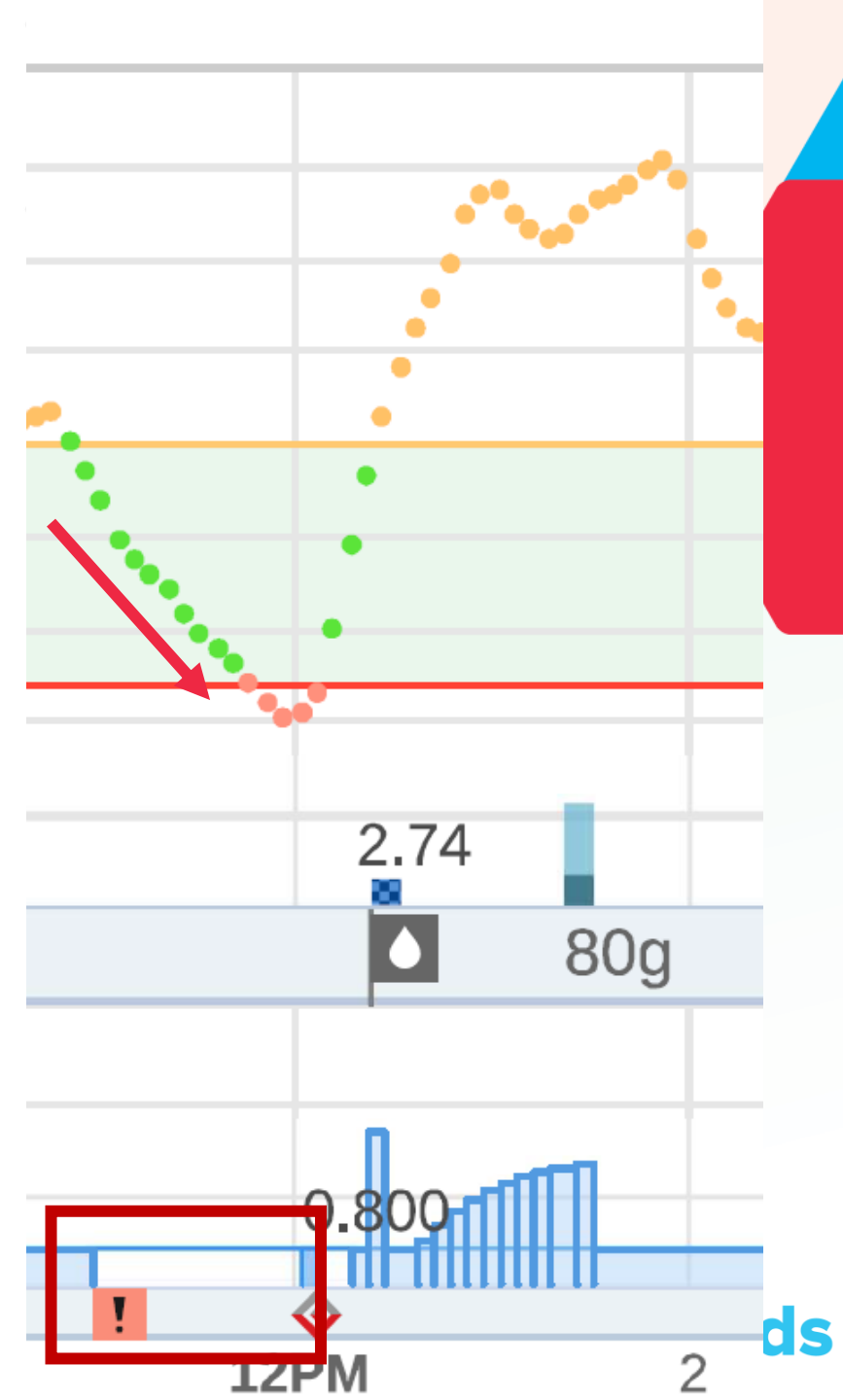
Low Blood Sugar Treatment

- Reminder: Confirm low glucose with blood glucose meter
 - CGM reading may lag behind blood glucose readings before and after treatment of low blood sugar



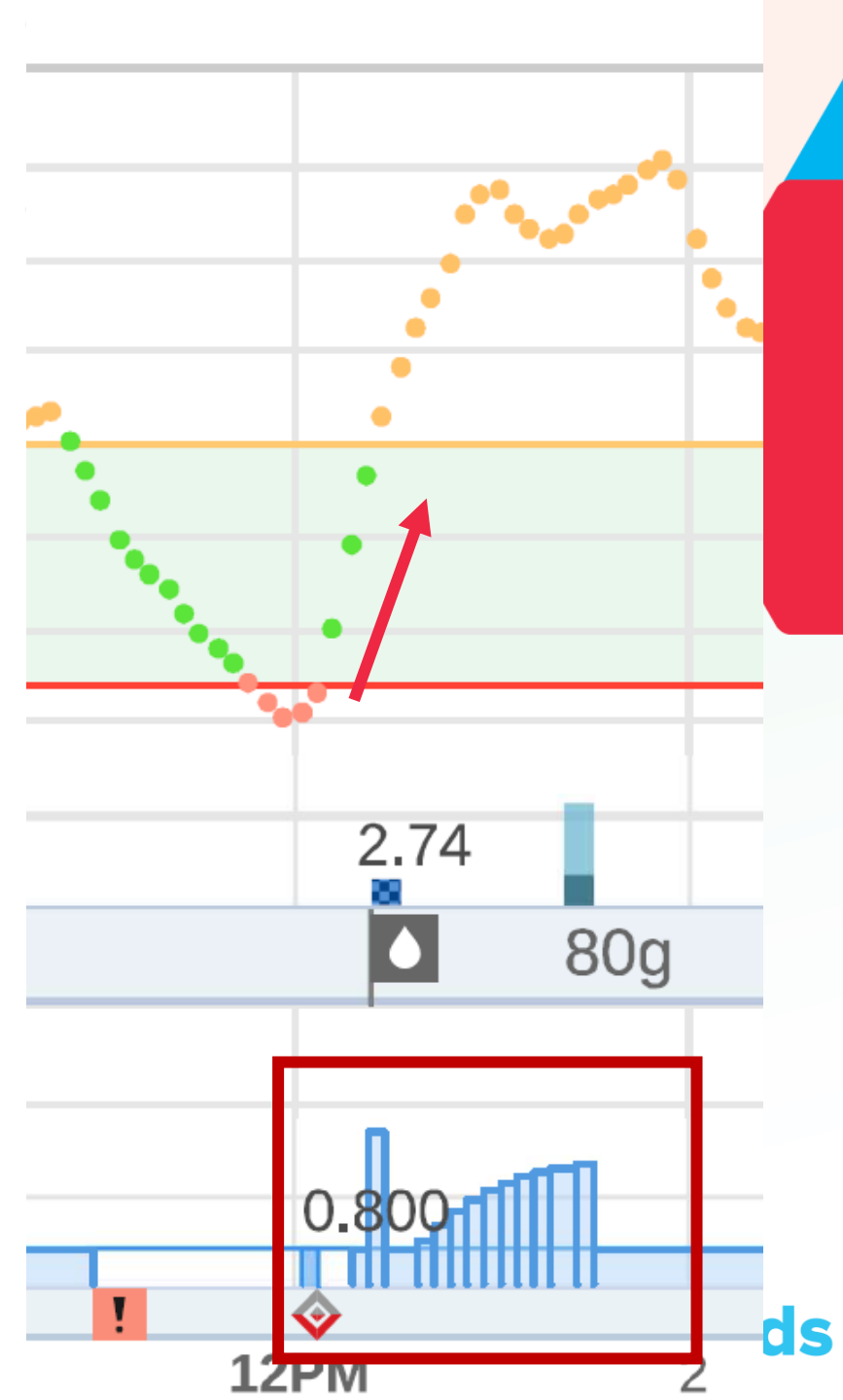
Low Blood Sugars

- Pump recognizes CGM trend ahead of hypoglycemia and reduces basal insulin delivery
- Less insulin on board ahead of the low means **fewer grams of carb may be needed for low blood sugar treatment**
- May **start hypoglycemia treatment with 5-10 grams of carb** (about half of usual treatment)



Low Blood Sugars

- Treating with more grams of carb than needed can cause “rebound” high blood sugars that result in increased insulin delivery (pump sees glucose rising)
- This can cause further hypoglycemia

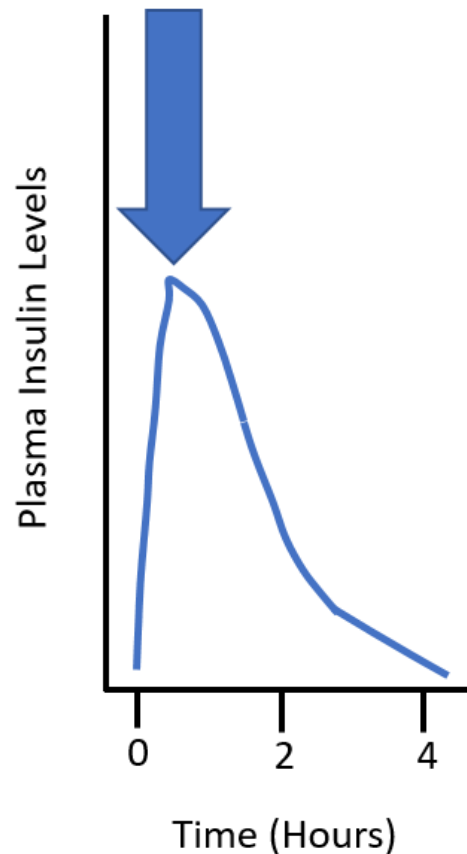


Don't Try to Trick the System!

- Entering carb grams/announcing a meal is a way users will sometimes cause the system to give additional insulin to bring high sugar levels down
- This can lead to long-term issues with the operation of the algorithm as it evaluates the response to insulin delivery that it assumes was from carb intake
- **Take away: Encourage users to do their part (give boluses for carbs/meals as appropriate, dose for correction if needed) and then let the system do its job.**

Administering Insulin Prior to Eating “Pre-Bolusing”

- Rapid-acting insulin is usually *starting to work* about 5-15 minutes after injection

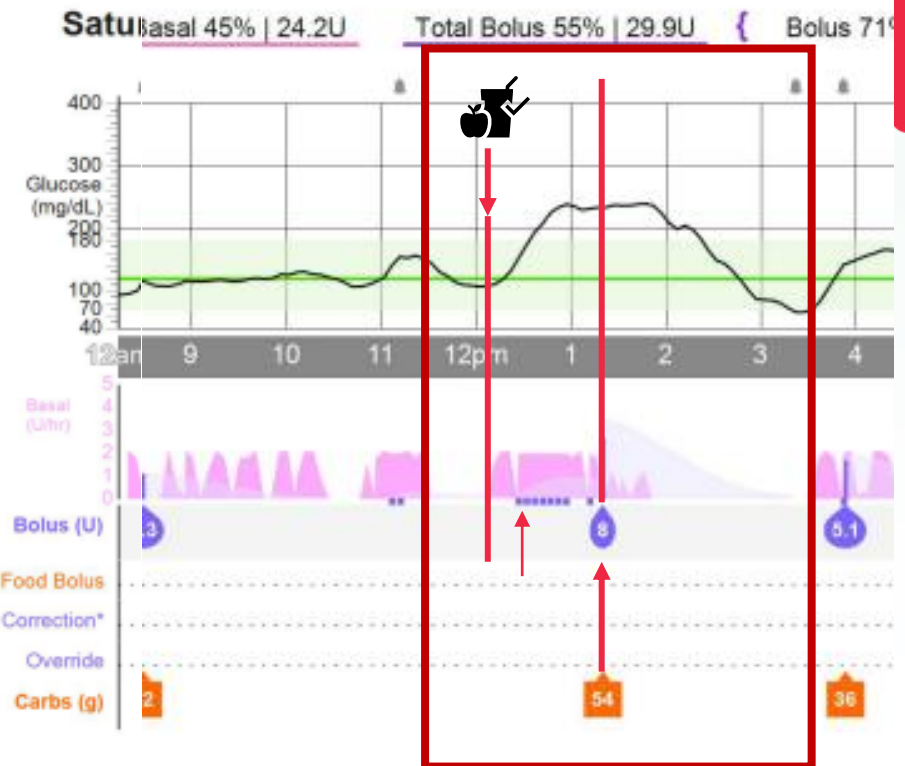


Administering Insulin Prior to Eating “Pre-Bolusing”

- Rise in glucose after starting to eat carbohydrates is typically rapid.
- **Administering insulin 5-15 minutes prior to eating (or longer depending on high blood sugar) helps match insulin action with carbohydrate intake,** may reduce spikes in sugar levels, and increase time in desired range.
- Pre-bolusing has definite practical challenges in many settings/age groups, including at school

LATE Meal Bolus Administration Can Cause Low Blood Sugars

- Rise in glucose after starting to eat carbohydrates is typically rapid (*as mentioned before*)
- AID systems automatically increase insulin delivery (basal rates and/or autoboluses) to address rapidly rising sugar levels
- Bolusing for the carb grams eaten (in addition to the increased insulin from the automated insulin delivery) can result in low blood sugars



Strategies for Late Meal Bolusing

- General
 - If recognize missed bolus early in eating, consider reducing carb dose (~50%) because basal insulin has already increased delivery
 - If recognized later (more than ~20 min) consider correcting high sugar reading
- Beta Bionics
 - **Within 30 min:** administer bolus
 - **After 30 min:** do not bolus, high blood sugar may last longer than expected

Traditional Recommendations for Exercise

Reduce insulin on board

- Decrease mealtime bolus prior to activity
- Decrease in basal rate set 30 min to 2 hours before activity (temp basal or programmed change)

Raise sugar levels with a snack



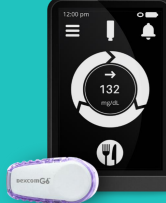

- Carbs given without insulin prior to activity

Note: These strategies are still valid and safe for users on injections or traditional pump (without automated delivery)

Exercise with AID Systems – Reducing Insulin On Board Before Activity

- Consider reducing meal boluses given 1-3 hours prior to exercise
 - May need to combine with activity feature
- Many pumps have an “exercise” or “activity” feature
 - These settings usually increase the blood sugar the pump is “aiming” for (target blood sugar)
 - This reduces the insulin delivery to allow the blood sugar to increase to the target setting
 - **To be effective these modes/features usually need to be started 30 min to 2 hours prior to activity** to make sure there is less insulin on board when the activity starts

Activity/Exercise Feature Details

				
Name of Feature	Temp Target	Exercise Activity	No Feature exists – can raise target to “Higher” OR remove pump for exercise	Activity Feature
Target when Feature is activated	150 mg/dL	140-160 mg/dL		150 mg/dL
Duration	30 min to 24 Hours (in 30 min increments)	30 min to 8 hours <i>(defaults to 30 min or last programmed value by user)</i>		Up to 24 hours <i>(in 1 hour increments)</i>
Automated Correction Boluses	Suspended	Automated Correction Boluses given if glucose predicted >180 mg/dL		N/A
Manufacturer Details About How to Activate/Use Feature	Setting Temp Target - MiniMed™ 780G System Support Medtronic (medtronicdiabetes.com)	https://www.tandemdiabetes.com/docs/default-source/quick-reference/quick-reference-exercise-activity-control-iq-ml-1011570.pdf	LA000061 B-Educational-Resource-Guide-v5.6-1-1.pdf (betabionics.com) (pg 18-20 have guidance about exercise)	https://www.omnipod.com/current-podders/resources/omnipod-5/videos/activity-feature

When to Consider Activity Mode

- Prior to planned physical activity/exercise
- May also be helpful for days where activity is increased – field days, field trips, walks, etc.
- Days when blood sugars trend lower than usual
- Anytime targeting a slightly higher BG may be desired
- May be useful in the hours after exercise

Exercise with AID Systems

- **AVOID strategies that undercount carbs or give carbs without insulin.**
 - Taking in uncovered carbs causes an INCREASE in the insulin because pump sees rise in sugar levels and increases insulin delivery to try to get levels back to target. **This can increase the risk of low blood sugar.**

Exercise with AID Systems

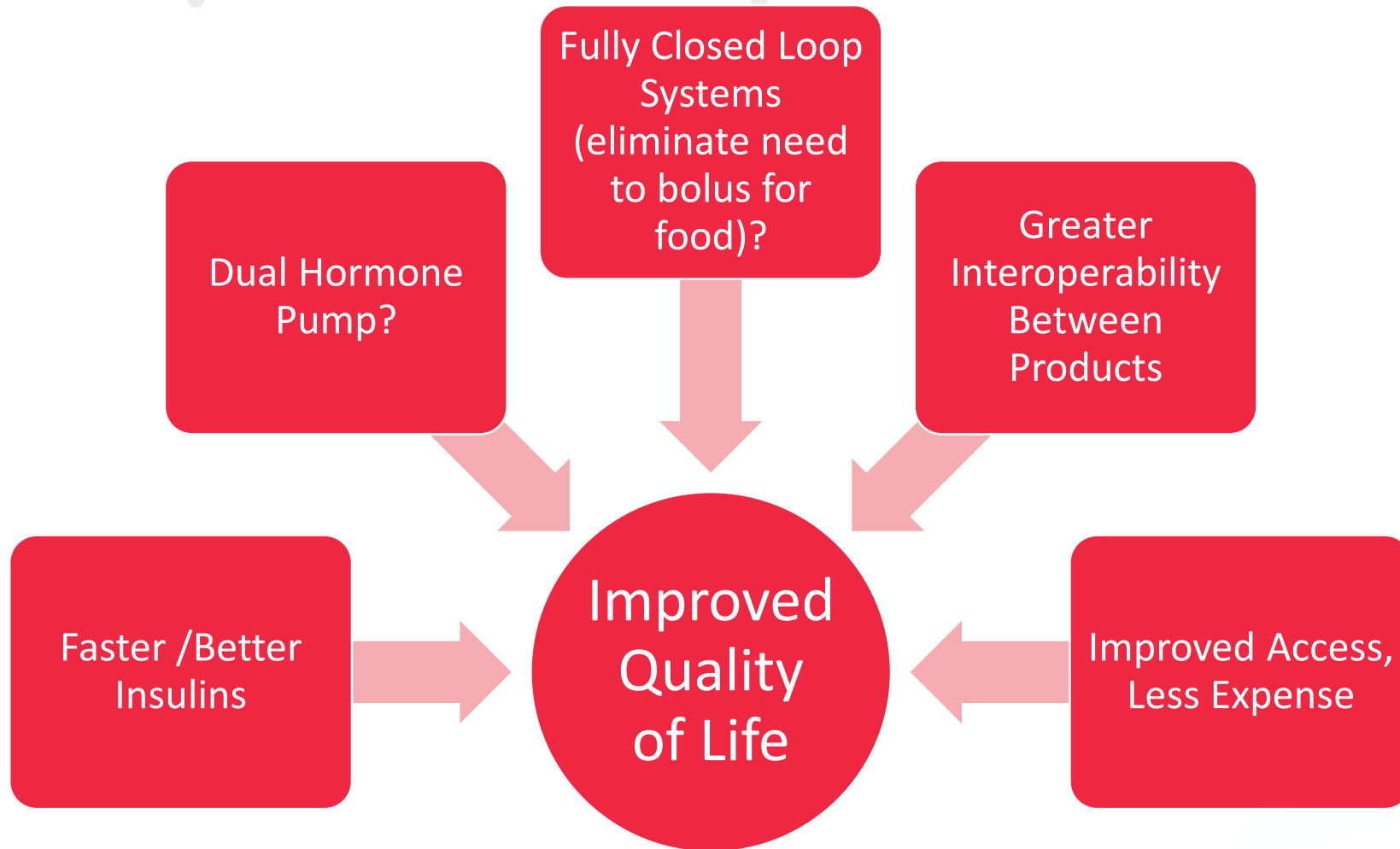
- If there is a need to use uncovered carbs (unplanned activity, etc.) users should consider
 - Leaving automated mode (entering manual mode*) **OR**
 - Disconnecting from pump and keeping pump out of range of CGM PRIOR to giving carbs to avoid additional insulin delivery

*Leaving automated mode often means surrendering desirable features like suspending insulin delivery prior to a low. Note that iLet pump does not have a manual mode option.

Exercise with AID Systems

- Some report success with taking in *small amounts of carb* (that don't result in glucoses above target) during activity to help sustain glucose levels *without* increasing insulin delivery
 - Think: sipping on full sugar Gatorade, taking a few gummy snacks, etc.

This is just the beginning...



	iLet Bionic Pancreas	MiniMed™ 780G	t:slim X2™ Control-IQ™	Omnipod® 5
				
CALCULATE	iLet	780G	Control-IQ	Omnipod 5
What is automation called?	iLet Bionic Pancreas	SmartGuard™	ControlIQ™	Automated Mode
Basal automation?	Insulin Automation is initialized by entering user's weight. Basal insulin delivery adjusts every 5 minutes based on CGM glucose trends and adapts over time based on the iLet's analysis of the user's daily glucose patterns.	"Auto Basal" calculated from total daily insulin, which is updated each day at midnight. Auto Basal is adjusted every 5 min based on recent CGM glucose trends, aiming for the target glucose value.	Increases or decreases the programmed basal rates based on a 30 min prediction of CGM glucose, aiming for the target glucose range.	"Adaptive Basal" calculated from total daily insulin, which is updated at each Pod change. Adaptive Basal is adjusted every 5 min based on a 60 min prediction of CGM glucose, aiming for the target glucose value.
Bolus automation?	All meal bolus doses and correction bolus doses are automated.	Auto correction boluses (max. every 5 min) if glucose is >120 mg/dL. Auto corrections can be turned on or off.	Auto correction boluses (max once/hr) if glucose is predicted to be >180 mg/dL in 30 min.	No automated boluses
Algorithm target glucose / target range?	3 target options: "Usual", "Lower", "Higher"	3 target options: 100, 110, 120 mg/dL	Target range: 112.5-160 mg/dL	5 target options: 110, 120, 130, 140, 150 mg/dL
Which insulin does the user give?	User completes a meal "announcement" to prompt the iLet to deliver a meal bolus, which involves indicating the carbohydrate amount for each meal ("Usual for Me"/"More" than usual/"Less" than usual).			



FIVE TIPS FOR DEVICE PLACEMENT

CHOOSE HEALTHY SKIN

Avoid broken skin, scabs, cuts, and scrapes, and any area of healing irritation. Wait at least a week before reusing a site.



PINCH IT UP

People wear sensors on many different parts of the body—abdomen, buttocks, hips, legs, arms, forearm. Choose an area that has enough fat to "pinch", and an area that is comfortable for you.



AVOID THESE AREAS

Areas to avoid include:
- Broken skin
- Redness
- Itching



ROTATE

Try to use as many sites as possible! Even if you use only one or two areas of the body, make sure to rotate sites 1-2 inches away from other sites.



SWOLLEN TISSUE

Insulin infusion can cause swelling under the skin called lipohypertrophy. If this is present, try not to inject insulin/place infusion sets in this tissue. CGM sensors are okay.



<https://www.pantherprogram.org/>

ADCES Danatech

- <https://www.adces.org/danatech/insulin-pumps>



Image: Medtronic.com



Image: ADA Consumer Guide



The Only Constant is Change.



Image: Tandemdiabetes.com



Image: Fiercebiotech.com



Image: ADA Consumer Guide

