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ESI INSULIN MANUAL

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8 Pumps, Continuous Glucose Monitoring System, and Hybrid Closed-loop Systems

Velmurugan Mannar, Saurav Das, Anand Vishal

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INTRODUCTION

Diabetes technology has advanced rapidly over the past few decades, with the introduction of continuous glucose monitoring (CGM) devices and insulin pumps, which deliver continuous subcutaneous insulin infusion (CSII), enabling tighter glycemic control with reduced treatment burden. These technologies provide real-time insights into glucose trends, support individualized therapy adjustments, and enhance safety through predictive alerts and automation. This chapter focuses on the principles and clinical use of CGMs and insulin pump technologies in contemporary diabetes management.

CONTINUOUS GLUCOSE MONITORING DEVICES

Continuous glucose monitoring system measures interstitial glucose levels in real time, reducing the need for frequent fingerstick testing. It provides continuous data with alerts for current or impending glycemic excursions or dips, enabling timely therapeutic adjustments and improved overall glycemic control.

Classification of Continuous Glucose Monitoring Devices

Continuous glucose monitoring devices **(Table 1)** are classified primarily based on how they deliver data to the user.

- *Real-time CGM (rtCGM)*: Continuously measures and displays glucose levels every 1–5 minutes without any action from the user. *Examples*: Dexcom G7, FreeStyle Libre 3/3 Plus, Medtronic Guardian 4, Eversense 365.
- *Intermittently scanned CGM (isCGM)*: Measures glucose continuously but requires scanning at regular intervals for visualization and storage of data. *Example*: FreeStyle Libre 2.
- *Professional (masked) CGM:* These are clinic-owned devices worn for 7–14 days, providing a glucose snapshot (often blinded), for clinical decision-making rather than for immediate self-management. *Examples*: Dexcom G6 Pro, FreeStyle Libre Pro, Medtronic iPro 2.

Indications for Continuous Glucose Monitoring

Continuous glucose monitoring is recommended for all individuals with type 1 diabetes mellitus

TABLE 1: Summary of commonly used CGM devices.

Feature	*Dexcom G7*	*FreeStyle Libre 3*	*Medtronic Guardian 4*	*Senseonics Eversense 365*
Sensor wear duration	10 days	14 days	7 days	365 days
Warm-up time	30 minutes	60 minutes	120 minutes	120 minutes
Sensor dimensions	47.6 mm × 5 mm	35 mm diameter × 5.2 mm	32 mm × 19 mm	Subcutaneous implant
Transmitter battery	6 months	Integrated with a sensor	7 years (rechargeable)	30 days (rechargeable)
Calibration required	No	No	No	2–3 daily
Data transmission	Bluetooth 5.3	Bluetooth Low Energy	Proprietary (pump-specific)	Bluetooth Low Energy
Display OPTIONS	Receiver, app, smartwatch	Reader, app	Pump display	App, wearable transmitter
Accuracy (MARD)	8.2%	9.2%	8.9%	8.7%
Low glucose detection	93.6% (≤70 mg/dL)	89–91% (≤70 mg/dL)	94% (≤70 mg/dL)	92% (≤70 mg/dL)
Hypoglycemia alert	20-minute urgent low soon	10-minute warning (reactive + trend)	60-minute predictive	30-minute predictive
FDA age approval	Age 2+	Age 4+	Age 2+	Age 18+
Closed-loop capable	Limited (some pump models)	No	Yes (MiniMed 780G only)	No (standalone only)
Unique advantage	Predictive alerts	Wear duration	Closed loop	Year-long implant

(T1DM), as well as those with type 2 diabetes mellitus (T2DM) who are on multiple daily insulin injections or using basal insulin but not achieving adequate glycemic control. It is particularly beneficial during pregnancy complicated by diabetes and in all individuals with recurrent hypoglycemia or hypoglycemia unawareness, where real-time glucose insights can improve safety and treatment outcomes.

Practical Aspects of Using Continuous Glucose Monitoring

Practical use of CGM involves attention to proper application, interpretation, and maintenance. A sensor is commonly inserted on the back of the upper arm, abdomen, or thigh. The skin should be cleaned with an alcohol wipe and allowed to dry before application to ensure optimal adhesion. Regular site rotation is recommended to prevent local skin reactions. After insertion, most sensors require a warm-up period during which glucose data is not available, and capillary glucose monitoring should be used to bridge this gap. Some systems (e.g., Medtronic Guardian 3, Eversense) require manual calibration with glucometer readings, whereas others are factory-calibrated (e.g., FreeStyle Libre 2/3, Dexcom G6/G7, Medtronic Guardian 4). Importantly, a confirmatory fingerstick glucose check should be performed whenever there is a discrepancy between symptoms and sensor readings.

Real-time CGM devices may provide trend arrows indicating the direction and rate of glucose change, along with programmable alerts for hypo- and hyperglycemia. Many platforms also allow remote data sharing with caregivers via smartphone applications.

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Cautions during the Use of Continuous Glucose Monitoring

While CGM offers significant clinical advantages, certain technical and practical limitations exist. CGM measures interstitial glucose rather than blood glucose, resulting in a physiological lag of approximately 5–15 minutes, which may reduce accuracy during periods of rapid glycemic change. Readings may also be falsely low when external pressure is applied to the sensor (e.g., during sleep). In addition, several medications and substances can interfere with sensor accuracy, typically leading to falsely elevated readings **(Table 2)**.

Continuous glucose monitoring devices must be removed before magnetic resonance imaging (MRI) or computerized tomography (CT) scans due to safety concerns. Accuracy may also be reduced in the hypoglycemic range, and confirmatory fingerstick testing is recommended when readings do not match symptoms. In addition, users may experience local adverse effects such as contact dermatitis, minor infections, bleeding, or hematoma formation at the insertion site. Sensors may also become prematurely dislodged due to sweating, friction, or adhesive failure, particularly in hot or humid climates.

Interpreting Continuous Glucose Monitoring Data and Report

Reliable interpretation of CGM data requires adequate data capture, typically defined as sensor use for at least 14 days with ≥70% active data collection. The ambulatory glucose profile (AGP) report is the standard format for analysis, presenting glucose data as a "modal day" with a median glucose line and interquartile and percentile ranges (e.g., 5th, 25th, 75th, and 95th percentile) to reflect glycemic patterns and variability **(Fig. 1)**. In addition to this aggregated view, individual daily profiles can be reviewed for more granular assessment.

Key CGM metrics **(Table 3)** provide a structured framework for clinical interpretation.

Time in range (TIR) reflects the proportion of time spent within target glucose levels and is the primary marker of glycemic control, with a general target of >70% for most adults with T1DM or T2DM, more stringent targets in pregnancy, and more relaxed targets (>50%) in older or high-risk individuals. Time below range

TABLE 2: Interfering substances and effect on commonly used CGM devices.

Medication	*Systems affected*	*Effect*
Acetaminophen: • >4 g/day • Any dose	• Dexcom G6, Dexcom G7 • Medtronic Guardian	Higher sensor readings than actual glucose
Ascorbic acid (vitamin C), >500 mg/day	FreeStyle Libre, FreeStyle Libre 2, FreeStyle Libre 3	Higher sensor readings than actual glucose
Ascorbic acid (vitamin C), >1,000 mg/day	FreeStyle Libre 2 Plus, FreeStyle Libre 3 Plus	Higher sensor readings than actual glucose
Hydroxyurea	Dexcom G6, Dexcom G7, Medtronic Guardian	Higher sensor readings than actual glucose
Mannitol (intravenously or as peritoneal dialysis solution)	Senseonics Eversense	Higher sensor readings than actual glucose
Sorbitol (intravenously or as peritoneal dialysis solution)	Senseonics Eversense	Higher sensor readings than actual glucose

Source: American Diabetes Association Professional Practice Committee. 7. Diabetes Technology: Standards of Care in Diabetes—2026. Diabetes Care. 2026;49(Suppl 1):S150-65.

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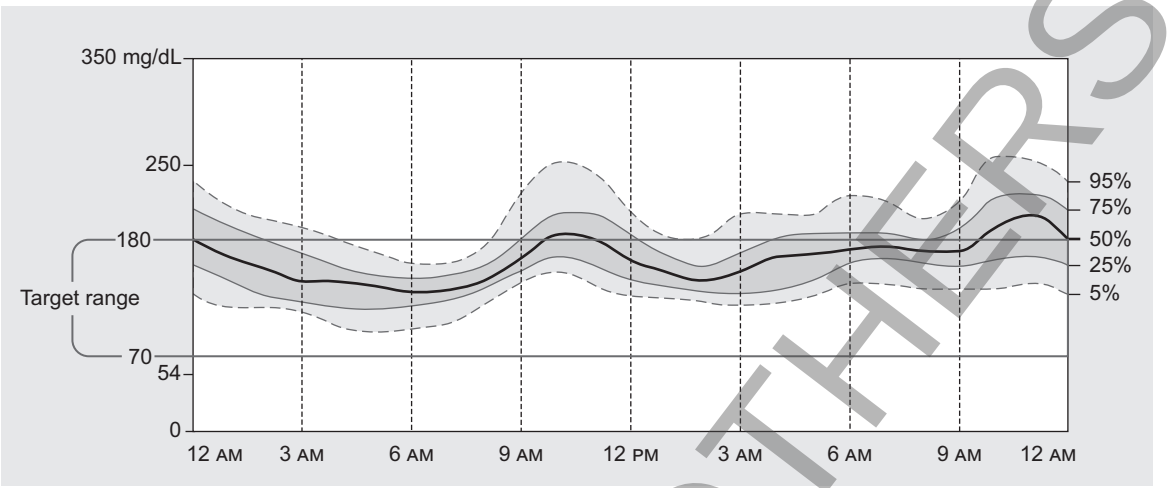

Fig. 1: Sample of the ambulatory glucose profile (AGP) report.

TABLE 3: Key continuous glucose monitoring (CGM) metrics and targets.

Metric	*Definition*	*Target (in general adults)*	*Special considerations*
Time in range (TIR)	% time glucose 70–180 mg/dL	>70%	*Pregnancy*: Lower range (≈ 63–140 mg/dL) *Older or high risk of hypoglycemia*: >50%
Time below range (TBR)	% time below target	<4% (<70 mg/dL) <1% (<54 mg/dL)	*Older or high risk of hypoglycemia*: <1% for <70 mg/dL
Time above range (TAR)	% time above target	<25% (>180 mg/dL) <5% (>250 mg/dL)	*Older or high risk*: <50% (>180 mg/dL) and <10% (>250 mg/dL)
Glucose management indicator (GMI)	Estimated HbA1c from CGM data	No fixed target	May differ from measured HbA1c in hemoglobinopathies
Coefficient of variation (% CV)	Measure of glycemic variability	≤36%	Higher values indicate unstable glucose patterns

(TBR) and time above range (TAR) quantify hypoglycemia and hyperglycemia, respectively, and should be minimized to reduce acute and chronic complications. The glucose management indicator (GMI) provides an estimate of HbA1c based on mean CGM glucose over approximately 10–14 days. Discrepancies between measured HbA1c and GMI may occur in conditions such as hemoglobinopathies. Glycemic variability is expressed as the coefficient of variation (% CV) and should ideally be ≤36%.

The AGP report allows identification of recurring patterns, such as postprandial hyperglycemia, suggesting the need for mealtime insulin adjustment or dietary modification, rising overnight glucose indicating insufficient basal insulin, or nocturnal hypoglycemia, pointing to excess basal dose or overcorrection of evening hyperglycemia. From a clinical perspective, prevention of hypoglycemia should take priority over correction of hyperglycemia.

INSULIN PUMPS

An insulin pump is an automated medical device that delivers rapid-acting insulin analogs through a subcutaneous cannula, with a steady basal rate for background metabolic needs, along with

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user-initiated bolus doses to cover meals and correct hyperglycemia. It aims to closely replicate endogenous physiological insulin secretion.

Classifications of Insulin Pumps

Insulin pumps can be classified based on their technological sophistication and physical design.

- *Technology-based classification*: From a technological perspective, the system may be open loop, sensor augmented, hybrid closed loop, or fully automated:
  - *Open loop systems*: Deliver insulin at fixed, preprogrammed basal rates, and the user must manually trigger bolus doses. They do not communicate with a CGM. *Examples*: Omnipod DASH (Insulet), MiniMed 630G (Medtronic).
  - *Sensor-augmented pumps*: Monitor CGM trends and automatically pause insulin delivery if they note or predict low blood glucose levels based on data. *Examples*: t:slim X2 with Basal-IQ (Tandem Diabetes), MiniMed 640G (Medtronic).
  - *Hybrid closed loop (HCL/AID)*: Use algorithms to automatically increase or decrease basal insulin and deliver auto-correction boluses continuously. Users must still count carbohydrates and announce meals to the pump for meal bolus doses. *Examples*: Omnipod 5 (Insulet), MiniMed 780G (Medtronic), t:slim X2 with Control-IQ (Tandem Diabetes).
  - *Advanced hybrid closed loop systems*: Remove the burden of carbohydrate counting. While true "fully closed loop" systems (no user input) are still in advanced clinical stages of development, some advanced hybrid systems in use require inputs only on weight (at initiation of pump) and meal size estimates (small/medium/large). *Examples*: iLet Bionic Pancreas (Beta Bionics), CamAPS FX (CamDiab).

  Table 4 summarizes commonly used insulin pumps.
- *Physical classification*: Insulin pumps may be either tubed or tubeless systems **(Fig. 2)**:
  - *Tubed (tethered) pumps:* Consists of a main reservoir and a computer connected to a subcutaneous cannula via thin, flexible plastic tubing. *Examples*: MiniMed 780G (Medtronic), t:slim X2 (Tandem Diabetes).
  - *Tubeless (patch) pumps:* Integrate the insulin reservoir, pumping mechanism, and cannula into a single adhesive pod that sits directly on the skin and is controlled wirelessly via a smartphone or handheld device. This "tubing-free" design is highly discreet and waterproof, allowing for

TABLE 4: Summary of commonly used insulin pumps.

Pump model	*Type*	*System*	*Global approval (FDA/CE)*	*CDSCO approval*
Medtronic MiniMed 780G	Tubed	Hybrid closed loop	FDA, CE	Approved
Insulet Omnipod 5	Tubeless	Hybrid closed loop	FDA, CE	Approved
Tandem t:slim X2	Tubed	Hybrid closed loop	FDA, CE	Approved
Beta Bionics iLet	Tubed	Advanced hybrid system	FDA	Pending/limited Import
Medtronic MiniMed 640G	Tubed	Sensor-augmented pump	FDA, CE	Approved
Omnipod DASH	Tubeless	Open loop	FDA, CE	Approved
Roche Accu-Chek Solo	Tubeless	Open loop	FDA, CE	Approved

(FDA: Food and Drug Administration; CE: Conformité Européenne; CDSCO: Central Drugs Standard Control Organization)

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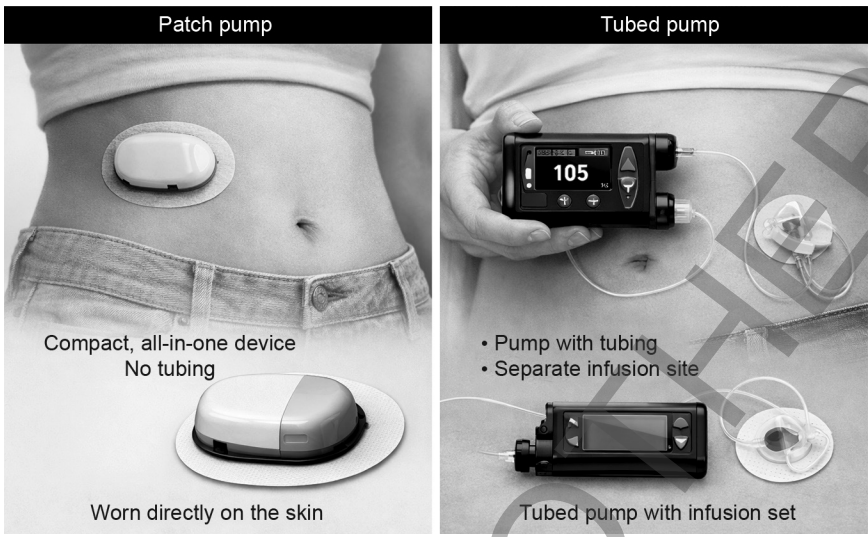

Fig. 2: Tubed versus tubeless pump.

uninterrupted insulin delivery during sports, swimming, or bathing. *Examples*: Omnipod 5 (Insulet), Accu-Chek Solo (Roche).

Indications for Insulin Pump Therapy

Insulin pump therapy is indicated for individuals with T1DM (both children and adults) who are able to use the technology safely and effectively. It may also be considered in people with T2DM who are on multiple daily injections or basal insulin but are not achieving adequate glycemic control. Additional indications include recurrent hypoglycemia or impaired hypoglycemia awareness, as well as "brittle" diabetes, characterized by marked glycemic variability or highly irregular lifestyles such as shift work and inconsistent meal patterns. Insulin pump therapy is also beneficial in pregnancy or during preconception planning and in specific conditions such as cystic fibrosis-related diabetes or diabetes following pancreatectomy.

Transitioning to Insulin Pump

Transitioning to open-loop insulin pump systems requires systematic calculation and individualization of both basal and bolus insulin parameters.

- *Total daily dose (TDD):* TDD is typically estimated from body weight, or as 75% of the prepump TDD in individuals who were adequately controlled before.

$$\text{TDD} = \text{Body weight (kg)} \times 0.5$$

- *Basal rate:* The basal insulin generally constitutes 40–50% of the TDD, and the basal rate is calculated as an hourly rate by dividing the basal requirement over 24 hours. This can be further tailored to circadian patterns using established basal profiles (e.g., Renner scale, King's modified basal profile). Temporary basal rate adjustments may be required in specific situations, e.g., 20–60% reduction during and after prolonged aerobic exercise, or 20–50% increase during acute illness, corticosteroid use, or the luteal phase in some women. Basal rates should also be fine-tuned based on glucose trends, with adjustments of 10–20% during specific time blocks if a consistent rise or fall in glucose occurs independent of meals or bolus insulin.
- *Bolus dose:* Bolus dosing is guided by key parameters, including the insulin-to-carbohydrate

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ratio (ICR), insulin sensitivity factor (ISF), and insulin-on-board (ICB):

- *Insulin-to-carbohydrate ratio* defines the amount of carbohydrate in grams covered by 1 unit of bolus insulin. ICR is commonly calculated by dividing 500 or 450 by the TDD for rapid-acting analogs.

  $$ICR = 500/TDD$$

  In hybrid closed-loop systems, this ratio may need to be strengthened by 10–20% compared to manual settings to manage postmeal spikes effectively.
- *Insulin sensitivity factor* defines the expected reduction in blood glucose with 1 unit of bolus insulin. It is calculated using the rule of 1,800 for rapid-acting analogs.

  $$ISF = 1,800/TDD$$

- *Insulin on board (IOB)* reflects the amount of residual active insulin remaining after the last bolus and is essential to avoid insulin stacking. The duration of action of rapid-acting analogs is usually set at 2.5–3 hours.

  Bolus dose may be calculated using these parameters by the formula:

$$\text{Bolus insulin dose} = \left(\frac{CHO}{ICR} + \frac{\text{Current BG} - \text{target BG}}{ISF}\right) - IOB$$

These parameters require periodic reassessment to maintain optimal glycemic control. Additionally, advanced bolus delivery patterns **(Table 5)** may be used to better match insulin delivery to meal composition and reduce postprandial glucose spikes.

When transitioning to hybrid closed-loop systems, basal rates are calculated by the system using algorithms, while carbohydrate counting and input for meal boluses are provided to the pump as in open-loop systems. Advanced hybrid closed-loop systems require inputs only on weight (at initiation) and meal size estimates as small, medium, or large.

Practical Aspects while on Insulin Pumps

Effective insulin pump use requires attention to several practical aspects of day-to-day management. Infusion sites should be rotated regularly to prevent lipohypertrophy and ensure consistent insulin absorption. During physical activity, activating a higher glucose target or "exercise mode" 1–2 hours in advance is recommended. If prolonged exercise is expected within 2 hours of a meal, the premeal bolus should be reduced by ~25–75% to minimize hypoglycemia risk.

When hypoglycemia occurs, particularly if the pump has already reduced or suspended insulin delivery, small amounts of fast-acting carbohydrates (5–10 g) are often sufficient to avoid overcorrection and rebound hyperglycemia. For planned fasting such as before medical procedures, the basal rate should typically be reduced by 20–30%, starting at least 2 hours prior.

TABLE 5: Bolus patterns and their uses.

Normal bolus	***Square-wave bolus***	***Dual-wave bolus***
Single waveform	Extended delivery	Percentage of insulin delivered as a rapid bolus
Rapid bolus	Even rate of insulin for a longer period	Remainder as an extended bolus
Ideal for a carbohydrate meal	Ideal for a protein/fat-rich diet with low carbohydrates, high fiber, and low glycemic index meals, gastroparesis, or eating over a prolonged period (e.g., parties)	Ideal for meals rich in carbohydrates, fats, and proteins

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TABLE 6: Limitations of insulin pump therapy.

Domain	***Issues/concerns***
Mechanical	*Infusion set failure*: Kinking, occlusion, accidental dislodgement, or leakage of the cannula interrupts insulin flow
	Rapid occurrence of diabetic ketoacidosis (DKA) risk in case of interruptions, due to a small subcutaneous depot and use of rapid-acting insulins
	Air bubbles in the system, sensor inaccuracies, and technical malfunctions: Impair accurate insulin delivery
	Cybersecurity risks due to wireless communication between components present a theoretical risk of unauthorized data interception or external control of insulin delivery
Dermatological issues	Lipodystrophy
	Contact dermatitis
	Site Infections
Psychological and system burden	*Alarm fatigue*: Constant notifications and alerts for glucose fluctuations may cause a significant psychological burden
	Diabetes distress: Increased stress or treatment discontinuation due to the efforts required in maintaining the system
	Sleep disruption: Poorly tuned alarms may cause frequent nocturnal awakenings

Suspected pump failure should be considered when glucose levels exceed 250 mg/dL and fail to decrease by at least 50 mg/dL within 1 hour of a correction bolus, in which case the infusion set should be changed promptly. If hyperglycemia persists with elevated ketones or if pump malfunction is confirmed, patients should transition to manual subcutaneous insulin injections and follow sick-day protocols. Importantly, all pump users should have a clear written backup plan and ready access to glucose monitoring tools and insulin for safe management in such situations.

Limitations of the Insulin Pump

Insulin pump therapy, while highly effective, is associated with a range of limitations spanning mechanical problems as well as dermatological and psychological issues **(Table 6)**.

CONCLUSION

Continuous glucose monitoring and insulin pump technologies have transformed modern diabetes management by enabling real-time glucose assessment and more physiological insulin delivery. Together, they improve glycemic control, reduce hypoglycemia risk, and support individualized therapy through data-driven decision-making and automation. However, optimal outcomes depend on appropriate patient selection, structured education, and careful interpretation of device data. Despite their advantages, these technologies have inherent limitations and require ongoing user engagement and clinical oversight. As systems continue to evolve toward greater automation, they are expected to further enhance safety, convenience, and quality of life for people living with diabetes.

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Self-Assessment Questionnaire

SECTION 2: Essentials of Insulin Therapy in Type 1 Diabetes

Eram Nahid

Question 1: A 22-year-old female enquires about her risk of developing type 1 diabetes mellitus (T1DM) and medications that might reduce her risk. She has a 25-year-old elder brother who was diagnosed with T1DM 7 years ago and is on insulin therapy. She has no polyuria or weight loss. Laboratory results revealed the following: Glycosylated hemoglobin (HbA1c) 6.3%, fasting blood glucose 110 mg/dL, 1-hour glucose 188 mg/dL, and 2-hour glucose 222 mg/dL on oral glucose tolerance test (OGTT) and detectable antibodies to glutamic acid decarboxylase 65 (GAD 65) and islet antigen 2 (IA-2).

Which of the following is the best next step in the management of this patient?

A. Measure HbA1c again
B. Initiate teplizumab therapy
C. Initiate insulin therapy
D. Refer for diabetes education

Answer: D. Refer for diabetes education

Teplizumab is approved for stage 2 type 1 diabetes. As this patient has a 2-hour plasma glucose value >200 mg/dL, she meets the criteria for stage 3 diabetes and is therefore not eligible for teplizumab therapy. The most appropriate initial step is referral for diabetes education. Repeating HbA1c would not alter management, and insulin therapy would be required after appropriate education.

Reference: Herold KC, Gitelman SE, Gottlieb PA, Knecht LA, Raymond R, Ramos EL, et al. Teplizumab: A Disease-Modifying Therapy for Type 1 Diabetes That Preserves β-Cell Function. Diabetes Care. 2023;46(10):1848-56.

Question 2: A 26-year-old man with 11-year history of T1DM has difficulty with hypoglycemia during exercise. He uses insulin pump with a continuous glucose monitoring system. He aims to jog for 30–60 minutes in the morning before eating or in the late afternoon 4–5 hours after lunch, but always develops hypoglycemia 15–30 minutes after starting to run. Reducing his basal insulin rate during exercise results in postexercise hyperglycemia.

Which of the following suggestions would be most appropriate to avoid hypoglycemia?

A. Reduce basal insulin by 50% at the beginning of exercise
B. Reduce pre-exercise meal bolus by 30–50%
C. Engage in resistance exercise before starting aerobic exercise
D. Consume 50–60 g of carbohydrates just before exercise

Answer: C. Engage in resistance exercise before starting aerobic exercise

Approach to adjusting insulin and carbohydrate is based on whether exercise will be conducted within 90–120 minutes of consuming a meal (high insulin state) or several hours after a meal (low insulin state). If exercise is conducted in high insulin state, reducing premeal exercise bolus is reasonable (B), but it is not applicable for this patient. 15–30 g of carbohydrate per hour during exercise is suggested to prevent hypoglycemia and 50–60 g carbohydrate snack is an excess quantity (D). Interestingly, resistance

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exercise (C) is associated with slight increase in blood glucose, due to increased circulatory levels of counter-regulatory hormones and metabolites that reduce glucose uptake in muscle. Studies suggested that resistance training before aerobic exercise reduces the risk of hypoglycemia during subsequent aerobic exercise.

Reference: Riddell MC, Gallen IW, Smart CE, Taplin CE, Adolfsson P, Lumb AN, et al. Exercise management in type 1 diabetes: a consensus statement. Lancet Diabetes Endocrinol. 2017;5(5):377-90.

Question 3: A mother whose child has T1DM seeks advice over the phone. She is worried as the child has nausea and diarrhea and is not eating, and his blood glucose is 350 mg/dL. She wants advice on whether she should give insulin and how much. What is the best advice for her?

A. Give oral fluids, stop insulin, and monitor blood glucose
B. Give oral fluids and give same dose of insulin
C. Give oral fluids and give extra dose of short-acting insulin
D. Give oral fluids, stop insulin, and monitor ketone in urine

Answer: C. Give oral fluids and give extra dose of short-acting insulin

The patient appears to be sick and is likely to be in diabetic ketoacidosis. Therefore, the mother should be instructed to follow sick day management guidelines. While oral fluid intake should be increased, insulin should not be discontinued as it will trigger or worsen ketosis (A and D). Current blood glucose is 350 mg/dL; therefore, he will require higher dose of short-acting insulin to lower the blood glucose (option C). Giving the same dose of insulin as before (B) will not help correct the hyperglycemia and the child may progress to severe diabetic ketoacidosis.

Reference: Lindholm Olinder A, DeAbreu M, Greene S, Haugstvedt A, Lange K, Majaliwa ES, et al. ISPAD Clinical Practice Consensus Guidelines 2022: Diabetes education in children and adolescents. Pediatr Diabetes. 2022;23(8):1229-42.

Question 4: With regards to mixing of insulins when on a split mixed regimen, which of the following statements are incorrect?

A. Rapid-acting insulin can be mixed with insulin glargine
B. Regular insulin if mixed with NPH should be used immediately
C. Regular insulin should be drawn first into the syringe and then NPH
D. NPH should be drawn first into the syringe followed by regular insulin

Answer: D. NPH should be drawn first into the syringe followed by regular insulin

Insulin glargine is formulated at a pH of 4.0 and should not be mixed in the same syringe with any another insulin or solution because this will alter its pH and thus affect its absorption profile. NPH insulin can be mixed with regular insulin, but regular should be drawn first (clear before cloudy) to avoid contamination of the regular insulin vial with protamine which may alter the pharmacokinetic properties of regular insulin in the entire vial.

Reference: Donnor T, Sarkar S. Insulin—pharmacology, therapeutic regimens and principles of intensive insulin therapy. In: Feingold KR, Adler RA, Ahmed SF (Eds). Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2000.

Question 5: A 21-year-old female with T1DM on a hybrid closed-loop insulin pump presents for follow-up. Her HbA1c is 6.8% but she reports frequent nocturnal hypoglycemia episodes despite following her pump's automated basal adjustments. Which of the following is the most appropriate next step in optimizing her therapy?

A. Increase the target glucose setting on the pump
B. Switch from rapid acting analog to ultra-rapid-acting analog in the pump
C. Reduce the carbohydrate-to-insulin ratio for meals
D. Convert to multiple daily injections with basal bolus regimen

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Answer. A. Increase the target glucose setting on the pump

Hybrid closed-loop systems automatically adjust basal insulin to maintain target glucose. Persistent nocturnal hypoglycemia indicates the pump's target may be set too low for safe overnight glucose control. Adjusting the pump target upward will reduce the risk of hypoglycemia. Switching to ultra-rapid insulin will not alter the outcomes (B). Reducing the carbohydrate-to-insulin ratio increases prandial insulin and may worsen hypoglycemia (C). Multiple daily injections are unnecessary and pump can be optimized (D).

Reference: Fuchs J, Hovorka R. Closed-loop control in insulin pumps for type-1 diabetes mellitus: safety and efficacy. Expert Rev Med Devices. 2020;17(7):707-20.

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Dr Kalra serves on the editorial board of numerous national and international journals and textbooks and has authored/edited more than 1,000 PubMed-indexed articles and chapters. These include national and global consensus on insulin use, insulin technique, and insulin motivation. He serves as Section Editor of the PubMed-indexed textbook, Endo Text, as well as Editor-in-Chief, Endocrine Society of India Textbook of Endocrinology.

His favorite hobbies, the traditional Indian folk dance, bhangra, and his exercise companion, the mugdar (Indian bell club), keep him company as he pursues his academic and literary career.

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