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Artificial Intelligence in Personalized Insulin Therapy for Diabetes Mellitus

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Abstract: Diabetes Mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia due to impaired insulin secretion, insulin action, or both, leading to serious complications affecting eyes, kidneys, nerves, and the cardiovascular system. Major advancements in diabetes care began with the discovery of insulin in 1921, transforming Type 1 Diabetes from a fatal disease to a manageable condition. However, conventional insulin therapy still struggles to mimic precise physiological glucose–insulin regulation. To overcome this limitation, Artificial Intelligence (AI) has emerged as a powerful tool in personalized insulin therapy, enabling real-time, data-driven treatment adjustments. Smart Insulin Pumps, or Artificial Pancreas Systems, utilize CGM feedback combined with AI algorithms for automated insulin delivery, significantly improving glycemic control and reducing hypoglycemia compared to traditional methods. Continuous Glucose Monitoring (CGM) integrated with AI enhances glucose trend prediction and enables closed-loop therapy for both Type 1 and Type 2 Diabetes patients. AI-based mobile health applications further support self-management by offering real-time alerts, behavioral guidance, and remote clinician monitoring. Predictive analytics now allow anticipation of hypo/hyperglycemia up to 120 minutes in advance, enabling personalized dose titration and reducing clinical inertia. Additionally, AI-driven Clinical Decision Support Systems (AI-CDSS) improve inpatient and outpatient insulin therapy safety by minimizing dosing errors and standardizing care workflows. Overall, integration of AI with advanced delivery devices and digital platforms marks a transformative shift from reactive to predictive and preventive diabetes management. These evolving technologies aim to achieve fully autonomous, closed-loop insulin therapy, improving quality of life and long-term outcomes for individuals with diabetes.

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I. INTRODUCTION

Diabetes is a metabolic disorder characterized by persistent hyperglycemia due to impaired insulin secretion, insulin action, or both. It affects the metabolism of carbohydrates, fats, and proteins, and long-term hyperglycemia can damage vital organs such as the eyes, kidneys, nerves, and heart [1]. The disease has been recognized for centuries—first described in ancient Egypt around 1500 BCE [2], and later called *Madhumeha* ("honey urine") in ancient India [3]. Aretaeus introduced the term "diabetes" in the 2nd century CE [4], and Thomas Willis added "mellitus" in the 17th century [5]. The link to pancreatic dysfunction was discovered in 1889 by Minkowski and von Mering [6], followed by the breakthrough discovery of insulin in 1921 by Banting and Best, which transformed diabetes treatment [7].

Type 1 Diabetes mellitus (T1D) is an autoimmune disorder that destroys pancreatic β-cells, resulting in total insulin deficiency [8]. Before insulin therapy, T1D was often fatal in children. The first therapeutic insulin was successfully used in 1922, earning Banting and Macleod the Nobel Prize in 1923 [9]. Research in the 1970s–80s confirmed the autoimmune nature of T1D through the detection of islet autoantibodies. Current advancements (2020–2025) focus on genetics, immunotherapy, β-cell regeneration, and artificial pancreas systems to improve glycemic outcomes [10].

Type 2 Diabetes mellitus (T2D) is the most prevalent form and involves insulin resistance with gradual β-cell failure [11]. Major risk factors include obesity, sedentary lifestyle, aging, genetics, and poor diet. If uncontrolled, complications include neuropathy, retinopathy, nephropathy, cardiovascular disease, and stroke [12]. Recent studies emphasize roles of gut microbiota, epigenetic changes, fatty liver, and circadian disruption in disease progression [13]. Management includes lifestyle changes, oral antidiabetics, and sometimes insulin therapy.

Gestational Diabetes Mellitus (GDM) occurs during pregnancy due to hormone-induced insulin resistance [14], generally resolving postpartum but increasing future T2D risk for mother and child [15]. First recognized as a distinct condition in the 19th–20th centuries [16], diagnostic criteria began with the O'Sullivan and Mahan OGTT method in 1964 [17] and later improved by international groups

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including WHO and IADPSG [18]. Poorly managed GDM can result in complications like macrosomia, pre-eclampsia, and neonatal hypoglycemia [19].

Other specific types of diabetes include MODY, caused by single-gene mutations and typically seen in younger individuals [20], and diabetes due to pancreatic diseases, endocrine disorders, infections, or long-term medication use (e.g., glucocorticoids, antipsychotics) [21]. These require accurate diagnosis to ensure appropriate personalized treatment [22].

➢ *Discovery of Insulin:*

The discovery of insulin is one of medicine's greatest breakthroughs. Before insulin, diabetes was a fatal disease managed only with strict starvation diets that slightly extended life but caused severe malnutrition. Insulin transformed diabetes from a deadly condition into a manageable one.

Key discoveries in the late 19th and early 20th century shaped our understanding of diabetes. In 1889, Minkowski and von Mering showed that removing the pancreas in dogs caused diabetes, proving its role in glucose control [23]. In 1901, Eugene Opie linked diabetes to damage of the islets of Langerhans [24]. By 1910, Sharpey-Schafer proposed that these cells produced a single substance—insulin—laying the foundation for future breakthroughs [25]. In 1921, Banting and Best successfully isolated insulin at the University of Toronto, with guidance from Macleod. By using duct-ligated dog pancreases, they extracted material that lowered blood sugar in diabetic dogs. Collip later purified it for human use [26]. In 1923, Eli Lilly began large-scale production of animal-derived insulin, which worked well but sometimes caused immune reactions due to differences from human insulin [27].

In 1955, Frederick Sanger determined insulin's full amino acid sequence, showing it has A and B chains linked by disulfide bonds. This first-ever protein sequencing earned him the 1958 Nobel Prize and opened the path to synthetic insulin [28]. In the 1960s–70s, chemically synthesized and highly purified insulins helped reduce allergic reactions. A major milestone came in 1978 when Genentech used recombinant DNA technology to produce human insulin in E. coli, enabling large-scale production. This led to the FDA approval of Humulin in 1982—the first biopharmaceutical drug [29]. During the 1990s–2000s, insulin analogs were developed to improve insulin action. Rapid-acting analogs (lispro, aspart, glulisine) provided quicker, shorter effects for meals, while long-acting analogs (glargine, detemir, degludec) offered stable basal coverage for 24–42 hours [30].

Insulin analogs greatly improved flexibility, glucose control, and reduced hypoglycemia. With digital advances, insulin pens (1980s) improved dosing accuracy, insulin pumps (2000s) enabled continuous infusion, and CGM devices added real-time glucose data. These innovations led to closed-loop "artificial pancreas" systems that automatically adjust insulin using smart algorithms [31]. In recent years, the incorporation of Artificial Intelligence (AI) and Machine Learning (ML) into insulin therapy has resulted in predictive glucose control systems that anticipate glucose variations and automatically adjust insulin delivery. Research has shown notable enhancements in time-in-range and a decrease in hypoglycemic episodes. By 2025, innovations will concentrate on oral and inhalable insulin formulations, nanoparticle-based insulin delivery, and gene or stem-cell therapies designed to restore natural insulin production [32].

II. AI APPLICATIONS IN INSULIN THERAPY

➢ *Smart Insulin Pumps (Artificial Pancreas Systems)*

The Artificial Pancreas, or Smart Insulin Pump, is a major innovation that monitors glucose and delivers insulin in real time, imitating the natural pancreas. Its development spans over 60 years, evolving from early continuous infusion ideas to today's advanced AI-based closed-loop systems.

Before the 1960s, insulin therapy relied on multiple daily injections, which poorly mimicked natural insulin release. In 1963, Dr. Arnold Kadish introduced the first automated insulin pump—a large, backpack-style device that delivered continuous insulin and glucose [33]. In the 1970s, Dean Kamen developed the AutoSyringe (AS6C), the first portable pump for continuous subcutaneous insulin infusion. It provided basal and bolus doses but lacked real-time glucose monitoring, so dosing still depended on manual testing [34]. In the 1980s–1990s, Continuous Glucose Monitoring (CGM) technology emerged using enzyme-based sensors to measure glucose in interstitial fluid. In 1999, Medtronic MiniMed released the first commercial CGM, recording glucose every five minutes for 72 hours [35]. By the early 2000s, CGMs were paired with insulin pumps to form sensor-augmented pumps (SAPs), which provided real-time glucose data but still required users to manually adjust insulin, keeping them as open-loop systems [36].

The Artificial Pancreas concept aims to mimic the body's natural insulin–glucose feedback using a closed-loop system where CGM data is processed by an algorithm that automatically adjusts insulin delivery [37]. Clinical trials in the mid-2000s by researchers like Hovorka and Kovatchev showed improved glucose control and reduced hypoglycemia [38] . In 2013, the FDA approved the Medtronic MiniMed 530G— the first pump with a threshold-suspend feature—marking an early step toward automated insulin therapy [39]. A major breakthrough came in 2016 with FDA approval of the Medtronic 670G, the first hybrid closed-loop insulin pump [40]. In 2020, the Tandem t:slim X2 with Control-IQ advanced glucose control using Dexcom G6 integration and MPC algorithms. That same year, Medtronic's 780G added automated correction boluses and Bluetooth-based remote monitoring, further improving automation and user convenience [41].

Since 2020, research has focused on fully closed-loop systems where algorithms automatically manage all insulin

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doses. The CamAPS FX became the first fully adaptive closed-loop system approved for all ages and pregnancy [31]. Open-source projects like OpenAPS, Loop, and AndroidAPS also allow users to build DIY artificial pancreas systems [42]. New dual-hormone systems delivering both insulin and glucagon show major benefits, reducing hypoglycemia by up to 70% compared to single-hormone pumps [43]. Dual-hormone artificial pancreas systems deliver insulin and glucagon, closely mimicking natural pancreatic function and reducing hypoglycemia by up to 70% [44]. AI algorithms like fuzzy logic and neural networks personalize insulin delivery. Systems such as Tandem Control-IQ, CamAPS FX, and Beta Bionics iLet offer cloud connectivity and remote monitoring [45]. Research is advancing toward nanotech insulin patches, non-invasive sensors, and multi-hormone systems to achieve fully automated, needle-free diabetes management by 2025 [32].

Table 1 Timeline Table Smart Insulin Pumps (Artificial Pancreas Systems)

Year	Key Development	Notes
Before 1960s	Multiple Daily Injections (MDI)	Inadequate imitation of natural insulin release.
1963	First automated insulin pump (Arnold Kadish)	Large backpack-style; continuous insulin infusion concept [33]
1970s	AutoSyringe AS6C (Dean Kamen)	First portable CSII pump; manual dosing [34]
1980s–1990s	Continuous Glucose Monitoring (CGM) development	Enzyme-based sensors for interstitial glucose [35]
1999	Medtronic MiniMed — First commercial CGM	5-min glucose recording for 72 hours [35]
Early 2000s	Sensor-Augmented Pumps (SAPs)	Open-loop systems — manual insulin adjustment [36]
Mid-2000s	Closed-loop clinical trials begin	Improved glucose control, reduced hypoglycemia [38]
2013	Medtronic 530G FDA-approved	Threshold-suspend insulin delivery [39]
2016	Medtronic 670G — First hybrid closed-loop	Automated basal insulin adjustment [40]
2020	Tandem t:slim X2 Control-IQ	Dexcom G6 + AI algorithm integration [41]
2020	Medtronic 780G	Auto-correction boluses + remote monitoring [41]
2021–2023	CamAPS FX approval	Fully adaptive closed-loop for all ages & pregnancy [31]
2020s	Dual-hormone APS (Insulin + Glucagon)	~70% ↓ hypoglycemia [43,44]
2023–2025	AI-based & DIY APS systems	OpenAPS, Loop, AndroidAPS [42,45]
By 2025+	Next-gen non-invasive nanotech & multi-hormone APS	Toward fully autonomous control [32]

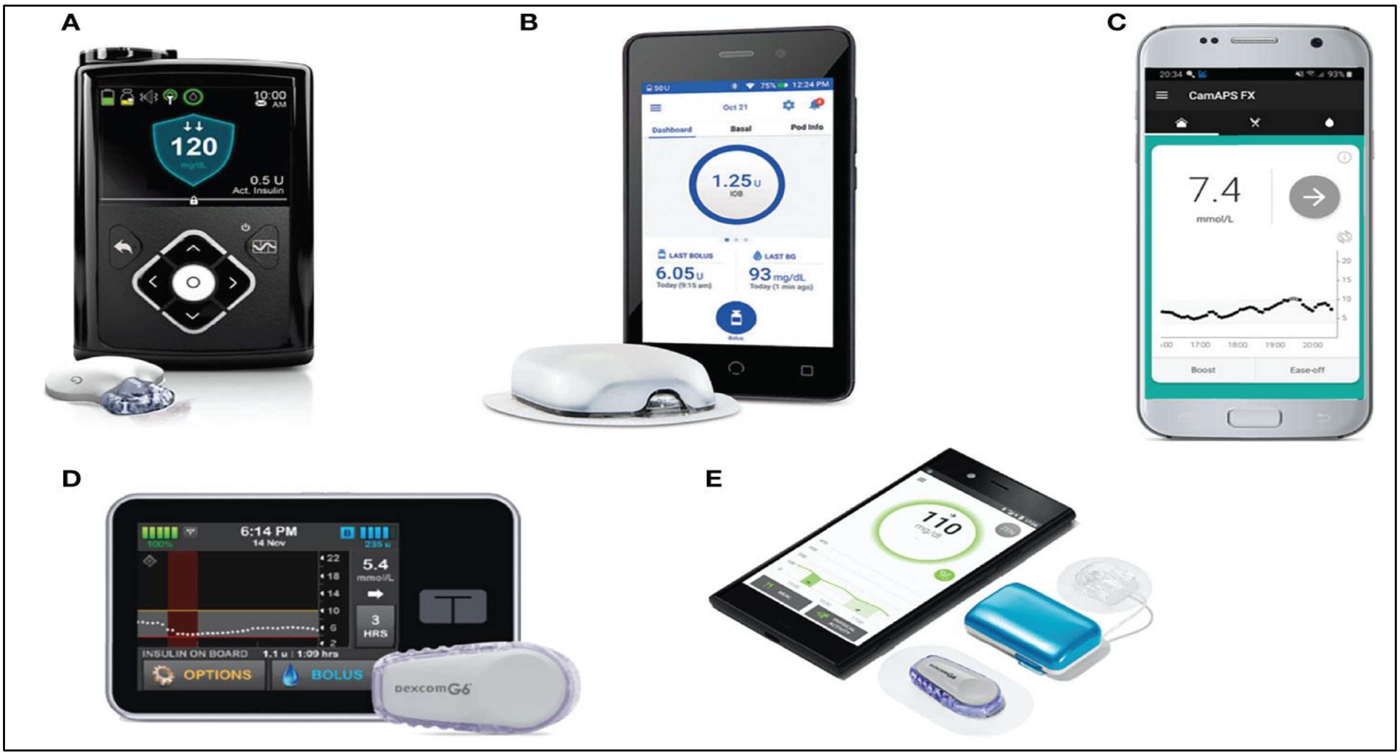

Fig 1 Here are some hybrid closed-loop systems that are currently available or in development: (A) MiniMed 670G with Guardian Link 3 sensor/transmitter , (B) Omnipod Horizon featuring a patch pump, (C) CamAPS FX algorithm operating on Android, (D) Tandem t:slim X2 pump combined with Dexcom G6 sensor, (E) Diabeloop DLBG1 algorithm integrated with Kaleido patch pump and Dexcom G6 sensor

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➢ *Continuous Glucose Monitoring (CGM) with AI :*

Continuous Glucose Monitoring (CGM) has transformed diabetes care by enabling real-time glucose tracking and supporting closed-loop insulin systems. Over five decades, CGM has evolved from early prototypes to AI-integrated devices, becoming a major advancement in diabetes management.

The concept of Continuous Glucose Monitoring (CGM) emerged in the 1960s, aiming to track glucose continuously rather than through periodic blood tests. A major step came in 1982 when Shichiri et al. developed the first implantable CGM sensor using glucose oxidase [46]. Through the 1980s–1990s, improvements in biosensor technology enhanced accuracy and biocompatibility, introducing microdialysis sampling and advanced electrochemical sensors [47]. The first commercial CGM prototype emerged in the 1990s from MiniMed (later Medtronic), capturing glucose data for up to 72 hours [48]. In 1999, Medtronic's MiniMed CGMS became the first FDA-approved CGM for clinical use, providing glucose readings every five minutes [49] . Later, real-time systems like Dexcom STS (2004), Abbott FreeStyle Navigator, and Medtronic Guardian REAL-Time introduced live alerts and wireless data transmission, greatly improving glucose control and diabetes management [50].

Advancements in CGM technology improved sensor accuracy and reduced calibration needs. Devices like Dexcom G4 (2012) and G5 (2015) brought MARD below 10%, making CGM readings close to lab accuracy [51]. Factory-calibrated sensors removed the need for daily finger pricks. Integration with insulin pumps led to sensor-augmented pump (SAP) systems, which provide predictive alerts and semi-closed-loop insulin delivery—moving closer to fully automated diabetes management [52]. Medtronic's Guardian Connect (2018) introduced AI-based alerts that predict high or low glucose levels 10–60 minutes before they happen. Dexcom G6 (2018) added cloud connectivity and smartphone sharing for real-time monitoring [53]. Machine learning models like RNNs and LSTMs analyze CGM data along with insulin, meals, and activity to predict future glucose trends and support better diabetes control [54].

AI has helped link CGM devices with digital health platforms for personalized treatment and remote monitoring. Systems like Tandem t:slim Control-IQ and CamAPS FX use predictive AI to automatically adjust insulin delivery [55] . From 2023–2025, development has focused on small, non-invasive sensors and fully automated monitoring systems. Examples include FreeStyle Libre 3, Dexcom G7, and the long-lasting Eversense implant, all with Bluetooth connectivity for continuous data sharing [56]. AI-powered CGM systems can now predict glucose levels 60–120 minutes in advance with over 90% accuracy. These systems use cloud-trained algorithms based on millions of glucose readings, improved through federated learning [57]. They also connect with wearables like activity and heart-rate monitors, along with nutrition apps, to build a patient "Digital Twin"—a virtual model that helps prevent glucose problems before they happen [32].

By 2025, CGM combined with AI will enable fully closed-loop insulin therapy, real-time remote monitoring for clinicians, and predictive analytics to improve diabetes care at the population level.

Table 2 Evolution of Continuous Glucose Monitoring (CGM) with AI

Year	**Major Milestone**
1960s	Concept of continuous glucose tracking emerges [46]
1982	Shichiri et al. develop first implantable CGM sensor (Glucose oxidase-based) [46]
1990s	Biosensor technology improves (microdialysis + electrochemical sensors) [47]
1990s	First MiniMed continuous glucose monitoring prototype (72-hour data) [48]
1999	MiniMed CGMS — first FDA-approved CGM, readings every 5 minutes [49]
2004	Dexcom STS: first real-time CGM with alert system [50]
2008	Abbott FreeStyle Navigator & Guardian REAL-Time introduced [50]
2012	Dexcom G4 brings accuracy <10% MARD [51]
2015	Dexcom G5 — wireless sharing with smartphones [51]
2018	Guardian Connect — AI-based prediction alerts 10–60 min ahead [52]
2018	Dexcom G6 — factory-calibrated, cloud-connected CGM [53]
2020	AI algorithms (RNN/LSTM) predict glucose trends automatically [54]
2021	Tandem Control-IQ & CamAPS FX AI closed-loop insulin delivery [55]
2023–2025	Libre 3, Dexcom G7, Eversense — ultra-small sensors + remote monitoring [56]
2024–2025	60–120 min predictive accuracy >90% with ML + federated learning [32]
2025	CGM + AI supports digital twin & population-level diabetes prediction [57]

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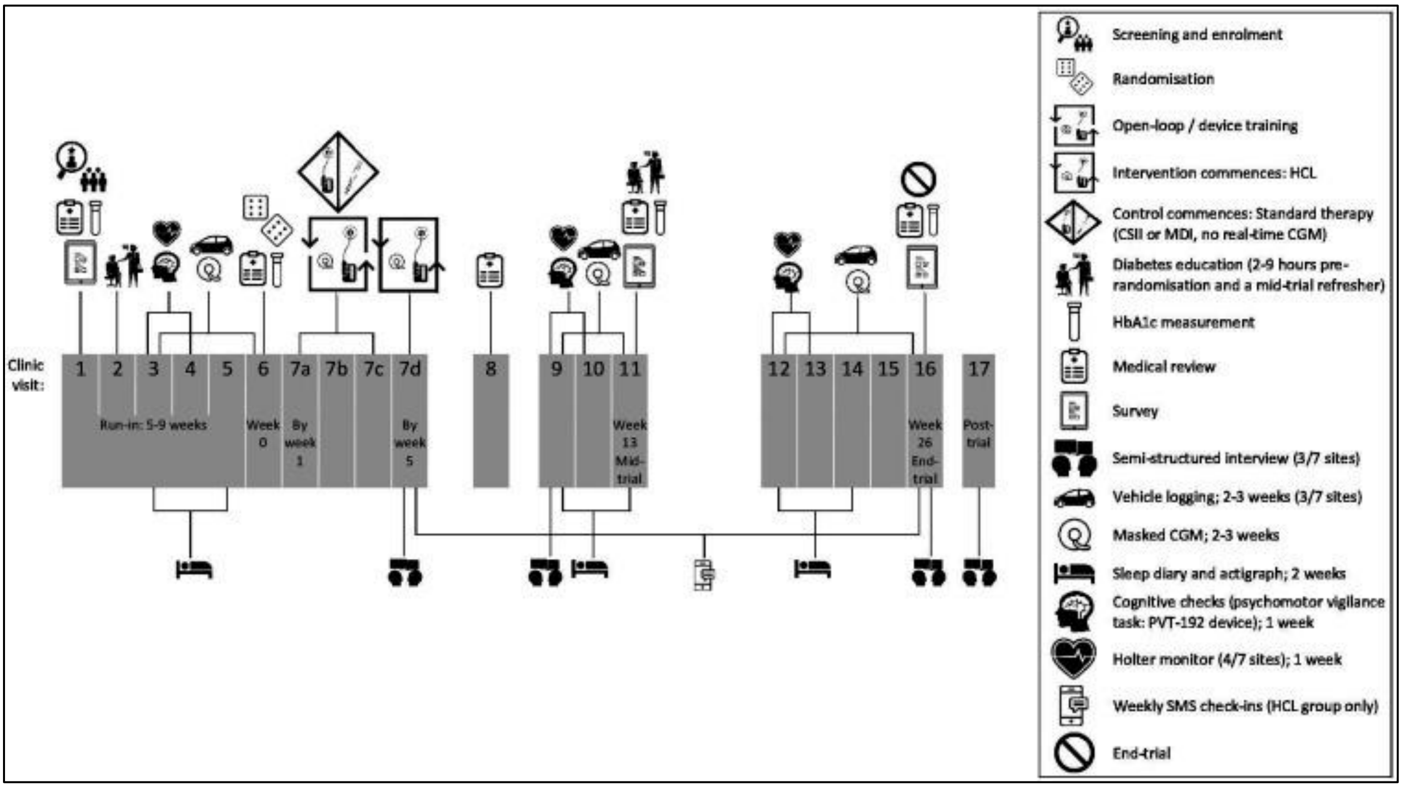

Fig 2 The study overview includes several important terms: CGM refers to Continuous Glucose Monitor, CSII stands for Continuous Subcutaneous Insulin Infusion, and HbA1c denotes Glycated Hemoglobin. Additionally, HCL is used for Hybrid Closed-Loop, MDI signifies Multiple Daily Insulin Injections, and SMS represents Short Messaging Service [31].

➢ *AI-Based Mobile App:*

The first mobile applications designed for diabetes management appeared in the early 2000s. These initial tools were basic logging systems to track blood glucose levels, insulin doses, dietary intake, and physical activity [58]. These applications largely depended on manual input and provided limited feedback or decision-making assistance. However, the introduction of smartphones in 2007 revolutionized this landscape by granting apps access to real-time data, cloud storage, and internet connectivity. This advancement enabled developers to connect glucose meters through Bluetooth and automate the process of data capture [59]. During the period from 2010 to 2015, artificial intelligence (AI) and machine learning (ML) techniques started to be integrated into mobile diabetes applications. These apps facilitated predictive analysis of blood glucose trends [60]. Automated alerts were also provided for impending hypoglycemia or hyperglycemia [61]. Early research indicated that AI-driven applications could enhance patient adherence, engagement, and glycemic control when compared to traditional manual logging systems [60].

The incorporation of continuous glucose monitoring (CGM) data has significantly improved these applications, allowing for personalized insulin and lifestyle recommendations tailored to each patient [62]. Since 2017, AI-driven mobile applications have advanced into complex platforms that integrate continuous glucose monitoring (CGM), insulin pumps, wearable activity sensors, and predictive analytics [63]. Modern applications like mySugr, Glooko, DreaMed Advisor, and BlueStar utilize machine learning to tailor their functions to each patient's unique patterns. This includes aspects such as glucose variability, meal consumption, physical activity, and sleep [64]. AI-powered platforms are capable of predicting glucose fluctuations up to 60 to 120 minutes in advance [65]. They can recommend adjustments to insulin dosages. They offer behavioral coaching and enable clinicians to monitor patients remotely [66]. Recent research carried out in 2025 emphasizes the significance of employing AI-driven digital twins and cloud-based models to customize therapy, improve time-in-range, and reduce the likelihood of hypoglycemia [67].

Such applications have become vital in precision diabetes care, seamlessly combining continuous monitoring, real-time analytics, and tailored recommendations to enhance patient outcomes.

Table 3 Mobile Apps & AI for Diabetes Management

Year / Period	Development / Milestone	Notes / Significance
Early 2000s	First mobile applications for diabetes (logging: glucose, insulin, diet, activity)	Basic digital version of manual logs; limited feedback [58].
2007	Release of smartphones (e.g. iPhone) — enabling better	Enabled cloud sync, meter/Bluetooth integration,

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	mobile health apps	real-time data [59]
2010–2015	Introduction of AI / machine-learning (ML) in diabetes apps for predictive glucose-trend analysis	Apps began offering predictions (hyper-/hypoglycemia risk) and early decision-support [60]
~2012–2018	Integration of CGM and device data with apps; linking pumps/sensors to mobile platforms	Enabled personalized insulin/lifestyle recommendations; closer to closed-loop ideas [63]
2017 onward	Advanced AI-driven platforms combining CGM, pump data, wearables, predictive analytics	Personalized care; trend prediction; remote monitoring [64]
2018–2022	Use of ML-based analytics for lifestyle factors (meals, activity, sleep) to estimate glucose variation	More holistic diabetes management beyond just glucose logging [65]
2023–2025	Emerging "Digital Twin" and cloud-AI models to customize therapy, improve time-in-range, reduce hypoglycemia	High accuracy predictions; population-level data; precision diabetes care [68]

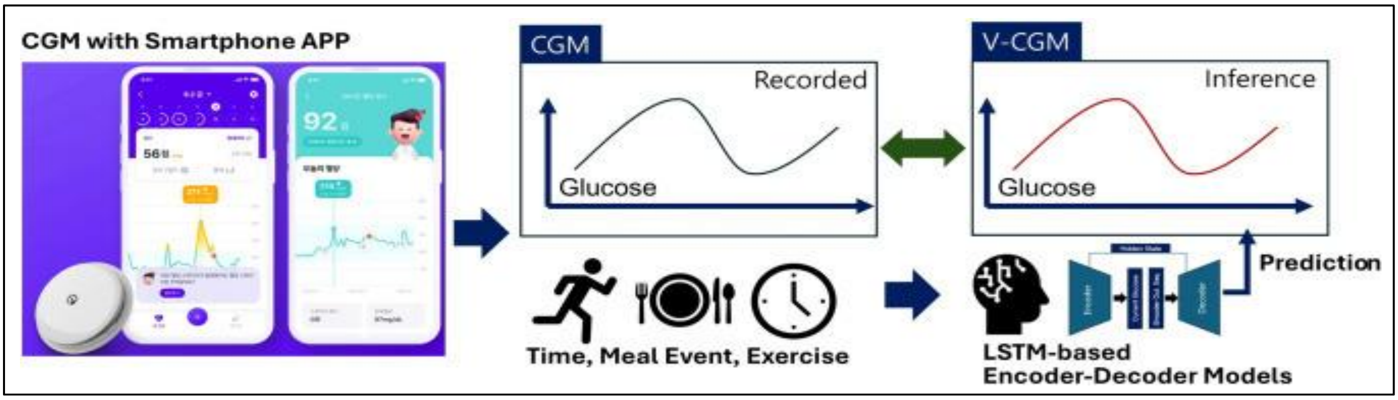

Fig 3 This Study Focuses on Continuous Glucose Monitoring (CGM) and Explores Virtual Continuous Glucose Monitoring (V-CGM) as well from Mobile App [57].

➢ *Predictive Analytics*

The application of predictive analytics in insulin dosing started with rule-based computerized protocols and evolved throughout the 2010s into sophisticated AI and machine learning systems. These modern systems combine various data streams—such as continuous glucose monitoring (CGM), insulin history, meal information, activity levels, sleep patterns, and stress factors—to accurately estimate near-term insulin requirements and recommend safer, personalized dosing [68]. Early advancements in machine learning demonstrated the potential to predict short-term glucose levels and identify impending hypo- or hyperglycemia from continuous glucose monitoring (CGM) data. This capability facilitated trend forecasting and allowed for proactive dose adjustments [69].

Clinical proof-of-concept studies have shown that AI-assisted insulin-titration decision support systems (iNCDSS) can meet or surpass traditional weight-based titration methods in managing glucose levels for inpatients [70]. Hospital implementation studies have demonstrated that iNCDSS can deliver safe and effective outpatient glycemic contraol that is comparable to clinician-guided titration, all while not raising the risk of hypoglycemia [71]. Reinforcement learning and model-based RL frameworks, developed between 2022 and 2023, have enhanced algorithms' ability to learn optimal insulin regimens from longitudinal patient data, thereby optimizing both safety and time spent within the target range [72]. In 2024, a comprehensive review validated that AI-driven insulin management systems enhanced therapy personalization and facilitated safer dose adjustments by evaluating continuous physiological and behavioral data [73].

A real-world study conducted in 2025 demonstrated that explainable machine-learning models provided consistent dosing recommendations and effectively reduced clinical inertia in everyday care environments [74]. A randomized controlled trial conducted in 2025, utilizing a digital-twin-enhanced decision-support system, showed enhanced post-meal glucose regulation and outcomes that were on par with those achieved by expert clinicians [75].

Table 4 Predictive Analytics in Insulin Dosing

Year / Period	**Key Development**
2010s	Shift from rule-based protocols to AI/ML for insulin dosing [68]
Early 2010s	ML used to predict glucose trends and hypo/hyperglycemia [69]
2018–2020	iNCDSS clinical pilot studies showing improved inpatient control [70]
2020s	Hospital and outpatient adoption of AI titration tools [71]
2022–2023	Reinforcement learning for optimized, personalized dosing [82]
2024	Reviews validating AI-based insulin dosing as safer and personalized [73]
2025 (Real-world)	Explainable ML reducing clinical inertia [74]
2025 (RCT)	Digital-twin system achieving clinician-level dosing outcomes [75]

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➤ *Decision Support Systems for Doctors:*

Decision Support Systems for Clinicians: A Journey from Rule-Based Protocols to AI-Driven Solutions. Initially, decision support systems for clinicians were based on rule-based computerized insulin protocols. They have now transformed into AI-driven clinical decision support systems (AI-CDSS) that evaluate multi-source patient data, including CGM, SMBG, EHR, medications, comorbidities, activity, and nutrition logs. This evolution enables personalized recommendations for insulin initiation and titration plans, ultimately minimizing dosing errors and standardizing patient care [84]. Early systematic reviews and technical assessments have demonstrated the feasibility and safety of both automated and semi-automated advisors for insulin adjustments. These evaluations indicate enhancements in workflow and a decrease in hypoglycemia when compared to unguided care [76].

In 2020, a groundbreaking proof-of-concept AI-DSS demonstrated that machine learning models can provide reliable basal/bolus recommendations and guidance to prevent hypoglycemia. This achievement involved training on real patient continuous glucose monitoring (CGM) and insulin data, marking a significant transition from in-silico studies to clinical validation [77]. Large contemporary reviews illustrate how AI-driven Clinical Decision Support Systems (AI-CDSS) integrate predictive models, clinical guidelines, and explainable machine learning to aid physicians in both inpatient and outpatient environments, ultimately helping to address clinical inertia [78]. Recent randomized multicenter implementation studies have demonstrated that real-time AI-assisted insulin titration tools can perform comparably to seasoned endocrinologists in adjusting dosages. Furthermore, these tools may enhance time-in-range without raising the risk of hypoglycemia, thereby supporting their safe clinical application [79]. Finally, the ongoing efforts from 2023 to 2025 will concentrate on several key areas: regulatory pathways, ensuring explainability, integrating with hospital electronic health records (EHRs), and conducting prospective trials. These trials aim to showcase the benefits in clinical outcomes and cost-effectiveness prior to broader adoption [80].

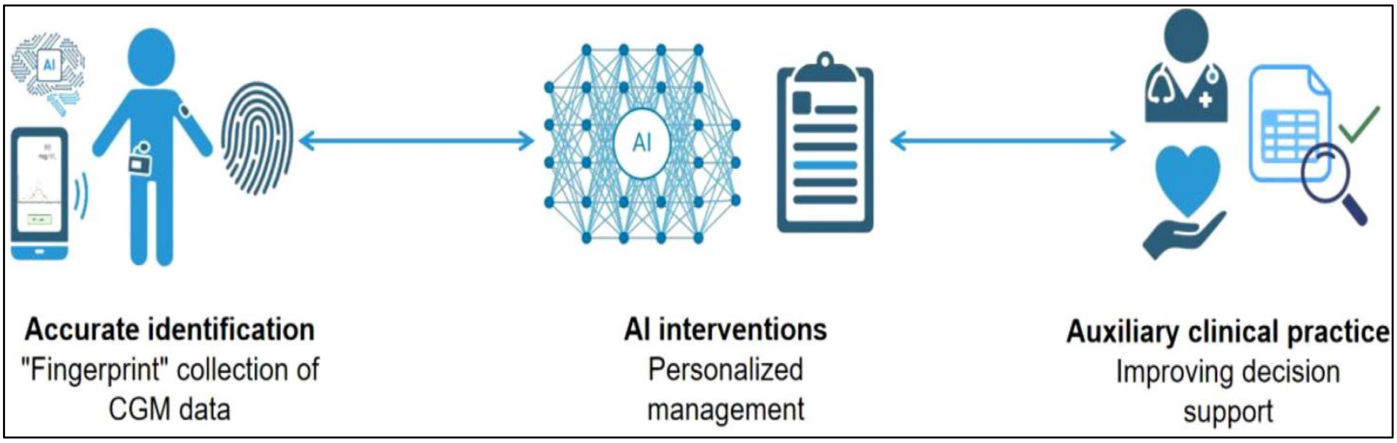

Fig 4 The illustration shows three key processes: accurate identification of glucose "fingerprint" data using CGM, AI-driven personalized interventions, and enhanced clinical decision support. CGM technology collects detailed glucose readings to form a unique data profile for each patient. These data are then analyzed by advanced AI models to identify patterns and guide individualized management strategies. Together, this integrated approach enables more precise care, smarter clinical decisions, and more effective overall diabetes management.[62].

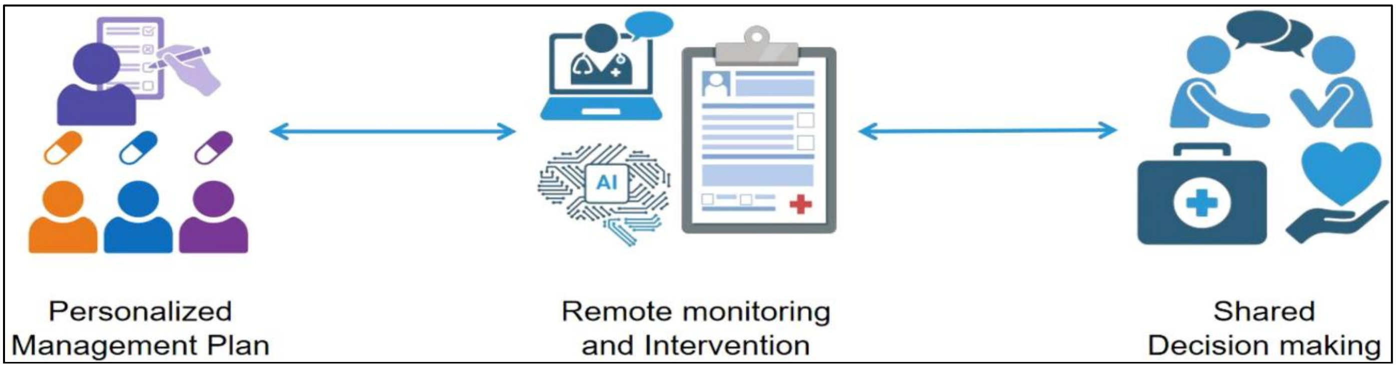

Fig 5 The diagram highlights how Personalized Management Plans, Remote Monitoring, and Shared Decision Making work together in modern healthcare. It begins with a Personalized Management Plan created by analyzing each patient's health status, lifestyle, and preferences. Remote Monitoring then provides continuous, real-time data, allowing healthcare providers to detect changes quickly and adjust treatment when needed. At the top, Shared Decision Making ensures open communication, enabling patients and doctors to discuss options together based on personalized plans and monitoring data. This integrated approach improves treatment adherence, strengthens trust, and supports more effective patient-centered care [62].

➢ *Future Prospects of AI in Personalized Insulin Therapy:*

The future of AI-driven insulin therapy is focused on achieving fully autonomous management of diabetes, significantly reducing the burden on both patients and healthcare providers. AI-enhanced insulin delivery systems will combine multi-hormone control, non-invasive sensors, and adaptive algorithms to more accurately replicate the natural functions of the pancreas [81]. Advancements in Digital Twin modeling will facilitate real-time optimization of therapy, enabling the prediction of personalized glucose responses to meals, exercise, and stress [82]. Additionally, federated learning and cloud-integrated platforms will facilitate insights at the population level while ensuring the protection of patient privacy[83].

AI-driven Decision Support Systems (DSS) are set to further integrate into everyday clinical care. They will offer clear, evidence-based insulin recommendations while ensuring real-time synchronization with Electronic Health Records (EHR) [84]. Future mobile applications will integrate behavioral coaching and mental health analytics to enhance adherence and achieve better long-term glycemic results [85]. The integration of AI with smart wearables, nanotech patches, and implantable biosensors is anticipated to enable needle-free, closed-loop treatments. This advancement promises to significantly decrease complications and enhance the quality of life for individuals living with diabetes [86].

III. CONCLUSION

Artificial Intelligence has become a significant transformative tool in managing diabetes, particularly in the realm of personalized insulin therapy. Over the years, diabetes has transitioned from a life-threatening disease to a manageable chronic condition, thanks to crucial advancements such as the discovery of insulin and innovations in insulin delivery technologies.The incorporation of digital technologies—such as Smart Insulin Pumps, Continuous Glucose Monitoring (CGM), AI-based mobile applications, predictive analytics, and AI-driven clinical decision support systems—has greatly enhanced glucose management. These advancements have lowered the risk of hypoglycemia and improved the overall quality of life for individuals living with diabetes.

Today's AI-driven closed-loop systems closely replicate natural pancreatic activity by automatically regulating insulin delivery based on real-time glucose data. This innovative approach shows significantly better results than conventional care methods.Moreover, mobile and wearable health technologies have facilitated remote monitoring, proactive treatment modifications, and heightened patient engagement, thereby enhancing precision therapy that is customized to individual metabolic differences. In addition, sophisticated predictive models and decision-support systems assist clinicians in optimizing therapy plans, increasing workflow efficiency while reducing treatment errors.

Looking forward, advancements like digital twins, non-invasive monitoring, nanotechnology-based delivery systems, and multi-hormonal artificial pancreas devices hold the promise of enhanced accuracy, safety, and personalization in diabetes care. Therefore, incorporating AI into diabetes management not only reflects current advancements but also paves the way toward a future of fully automated, highly precise, and patient-centered diabetes therapies, which could significantly lessen long-term complications and alleviate the global healthcare burden.

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