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THE ROLE OF ARTIFICIAL INTELLIGENCE IN PERSONALISED TREATMENT AND GLUCOSE MONITORING FOR DIABETES MANAGEMENT

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INTRODUCTION

Artificial Intelligence (AI) involves designing computer systems capable of imitating human cognitive abilities, including reasoning, learning, and independent decision-making.[1] Within healthcare, AI is being applied with growing frequency to monitor patient wellbeing, diagnose disorders, design treatent strategies, and predict future clinical outcomes.[2] One field benefiting considerably is personalised medicine, which tailors healthcare delivery to a patient's individual genetic profile and lifestyle, thereby improving the precision and effectiveness of medical interventions.[3]

Fundamentals of AI in Diabetes Management

In diabetes care, AI is chiefly used to improve Continuous Glucose Monitoring (CGM) technology, anticipate fluctuations in blood glucose, support automated insulin delivery through so-called “artificial pancreas” systems, and generate personalised health alerts.[4] Earlier approaches to diabetes management relied on fixed insulin regimens and manual testing, whereas modern care increasingly incorporates AI within mobile health applications and automated delivery systems.[5] Notable advances include CGM devices with built-in predictive analytics for blood glucose fluctuations, autonomous “artificial pancreas” systems for insulin delivery,[6] wearable devices and smartphone applications that enable real-time data sharing, and deep-learning models that analyse individual patient patterns to refine therapy.[7]

AI-Driven Advancements in Glucose Monitoring and Prediction

AI relies on sophisticated algorithms and computational frameworks to interpret complex datasets and identify meaningful trends.[8] Its principal roles in diabetes care include early disease detection, blood glucose forecasting, automated insulin administration, and the provision of tools that enable patients to manage their own health.[9] Machine learning (ML) and deep learning (DL) have fundamentally reshaped the management of chronic conditions such as diabetes. AI-enhanced CGM systems can now project blood glucose levels 30 to 60 minutes in advance, supporting the early detection of complications such as nocturnal hypoglycaemia.[10] These predictive models draw on a range of data points, including historical CGM readings and insulin dosages, dietary intake and physical activity levels, and sleep quality together with psychological stress.[11] Techniques such as Long Short-Term Memory (LSTM) networks and Recurrent Neural Networks (RNNs) are frequently applied to analyse these data sequences. AI is also driving the development of non-invasive monitoring tools that use optical sensors or biosensors to estimate glucose levels without conventional finger-prick testing.[12]

AI in Personalised Diabetes Treatment and Decision Support

AI is transforming diabetes therapy by providing real-time clinical support and individualised care, thereby improving overall glycaemic control and patient quality of life.[13] Contemporary AI algorithms can recommend precise insulin doses based on a patient's unique history and current activity, and can additionally assess a patient's specific risk of complications such as cardiovascular disease, renal impairment, or retinopathy. Clinical Decision Support Systems (CDSS) similarly use patient data to help healthcare providers select the most effective combinations of medication and lifestyle adjustment. Examples of such platforms include DreaMed Advisor Pro and IBM Watson.[14]

Clinical Implementation

Implementing AI within a clinical setting requires these tools to integrate seamlessly with Electronic Health Records (EHRs) and to comply strictly with privacy regulations such as HIPAA and GDPR. For such tools to be effective, they must support, rather than disrupt, the existing workflows of healthcare providers.[15]

User Adoption

Research indicates that patients are increasingly willing to use AI-integrated wearable devices, provided the technology is perceived as accurate and trustworthy. Patient education plays a vital role in this process, as digital literacy and cultural relevance are essential for the widespread success of these interventions.[16]

CURRENT CHALLENGES

The performance of AI depends heavily on the quality of the data used to train it, and several challenges remain. Data quality: incomplete or inaccurate data labels can reduce model precision. System bias: if training data lacks diversity, AI may perform poorly for certain demographic groups, potentially worsening existing health inequalities. Transparency: clinicians often distrust "black-box" models that cannot clearly explain their reasoning. Cost: many AI platforms are not yet covered by insurance, which limits access for low-resource communities.[17]

FUTURE DIRECTIONS

The next phase of AI in diabetes care is expected to focus on "explainable AI" to build trust through transparent decision-making. Integration with "digital twins"—virtual replicas of individual patients—may allow clinicians to test treatment outcomes before applying them in practice. Efforts are also underway to develop affordable AI solutions that promote global health equity, along with dynamic regulatory frameworks suited to systems that continue to learn and evolve.[18,30]

Oral Antidiabetic Drugs (Type 2 Diabetes)

1. Biguanides: Metformin, a first-line agent, decreases hepatic glucose production and improves insulin sensitivity.
2. Sulfonylureas: Glibenclamide, glimepiride, and gliclazide increase insulin secretion but carry a risk of hypoglycaemia.
3. Meglitinides: Repaglinide and nateglinide act as short-acting insulin secretagogues.
4. Thiazolidinediones (TZDs): Pioglitazone and rosiglitazone increase insulin sensitivity; side effects include weight gain and oedema.
5. Alpha-Glucosidase Inhibitors: Acarbose and miglitol delay carbohydrate absorption and may cause gastrointestinal side effects.
6. DPP-4 Inhibitors (Gliptins): Sitagliptin, vildagliptin, saxagliptin, and linagliptin increase incretin levels and carry a low risk of hypoglycaemia.
7. SGLT-2 Inhibitors: Dapagliflozin, empagliflozin, and canagliflozin increase urinary glucose excretion and offer cardiovascular and renal benefits.

Injectable Antidiabetic Drugs

8. GLP-1 Receptor Agonists: Liraglutide, exenatide, and semaglutide increase insulin secretion and promote weight loss.[31,34]

Insulin Types (Pharmacological Classification)

Insulin is primarily classified according to its onset, peak, and duration of action, a classification that is essential for diabetes treatment planning.[26]

1. Rapid-Acting Insulin

Onset: 10–15 minutes | Peak: 1–2 hours | Duration: 3–5 hours

Use: taken before or immediately after meals.

Examples: insulin lispro, insulin aspart, and insulin glulisine.

2. Short-Acting Insulin

Onset: 30–60 minutes | Peak: 2–4 hours | Duration: 6–8 hours

Use: given 30 minutes before meals.

Example: regular (human) insulin.

3. Intermediate-Acting Insulin

Onset: 1–2 hours | Peak: 6–12 hours | Duration: 12–18 hours

Use: basal insulin, often administered twice daily.

Example: isophane insulin (NPH).

4. Long-Acting Insulin

Onset: 1–2 hours | Peak: minimal or no pronounced peak | Duration: up to 24 hours

Use: provides stable basal insulin coverage.

Examples: insulin glargine and insulin detemir.

5. Ultra-Long-Acting Insulin

Onset: approximately 1 hour | Peak: no pronounced peak | Duration: greater than 36–42 hours

Use: basal control with very stable glucose levels, given once daily.

Example: insulin degludec.

6. Premixed Insulin (Combination)

Composition: a combination of intermediate-acting insulin with short- or rapid-acting insulin.

Advantage: simplified dosing with fewer injections.

Examples: 70/30 (NPH + regular), 75/25, or 70/30 (lispro/aspart + protamine).

1. Next-Generation Insulin and Delivery Methods

Needle-Free Insulin Gels

Researchers have developed a polymer-based insulin gel that can be applied topically without the need for injections. In animal studies, the gel normalised blood glucose levels over several hours, suggesting it may offer a viable future option for individuals who cannot tolerate injections.[32]

Smart Insulin Patches

Efforts are underway to develop "smart" patches fitted with glucose-responsive microneedles that automatically release insulin as blood glucose levels rise, a development that could considerably simplify insulin administration.

Weekly and Oral Insulin Options

Weekly basal insulin injections and oral insulin formulations, currently undergoing clinical trials, could reduce or eliminate the need for daily dosing if proven safe and effective.

2. Advanced Monitoring and Automated Systems

Artificial Pancreas and Closed-Loop Systems

By combining automated insulin pumps with continuous glucose monitoring (CGM) to adjust dosing in real time, these systems function much like a self-regulating pancreas. Such devices are already available and are being refined rapidly.[32,34]

AI and Digital Health Tools

The development of AI-driven applications and algorithms capable of forecasting glucose trends, recommending behavioural adjustments, and optimising insulin dosing could considerably simplify and personalise diabetes care.[29]

Digital Twin Models

Research into "digital twin" systems—which simulate patient-specific data to recommend optimal lifestyle and insulin choices—may further improve glucose management.

3. Immune and Cell-Based Therapies

Immunotherapy (e.g., Teplizumab)

By modifying immune activity, newer immunotherapies such as teplizumab can delay or reduce the onset of Type 1 diabetes, particularly when administered early to at-risk individuals.[21,22,25]

Beta-Cell Replacement and Transplantation

Researchers are exploring the use of stem cells to replace damaged insulin-producing beta cells as an alternative to lifelong insulin therapy. Some approaches are being developed without strong immunosuppressants in order to reduce the risk of immune rejection.[23,24]

Gene-Edited Cell Transplants

In a landmark case, an individual with Type 1 diabetes began producing their own insulin following transplantation of CRISPR-edited islet cells engineered to evade immune attack—representing a significant step toward a durable treatment or potential cure.[28]

4. New Drugs and Metabolic Targets

Emerging oral medications may offer fewer adverse effects than existing treatments while simultaneously promoting fat metabolism, regulating blood glucose, and preserving muscle mass.[27]

Gene-Therapy-Based Approaches

Experimental therapies, such as Rejuva, aim to use viral vectors to prompt pancreatic cells to produce beneficial hormones such as GLP-1 over extended periods, potentially reducing or eliminating the need for chronic medication.

Microbiome and Inflammation Targets

Researchers are investigating the roles of gut microbiota and inflammatory proteins in diabetes, which may lead to entirely new therapeutic approaches targeting the underlying metabolic mechanisms of the disease.

5. Holistic and Integrated Care

Telemedicine and Remote Monitoring

Telehealth and continuous remote monitoring have become essential components of diabetes management, enabling clinicians to make more frequent and efficient adjustments to treatment.

AI-Powered Prediction and Prevention

AI-based techniques are being developed to assess an individual's risk of developing Type 1 diabetes before symptoms appear, potentially enabling earlier intervention.

Future Prospects for Diabetes Treatment

Greater convenience: fewer injections, smarter devices, and wearable technology.

Improved glucose management: automated, AI-guided insulin delivery.

Disease-modifying treatments: immunotherapy and gene- or cell-based therapies that aim not only to treat diabetes but also to delay, prevent, or potentially cure it.

Personalised medicine: treatments increasingly tailored to individual biology and lifestyle.

CONCLUSION

While the rising global prevalence of diabetes represents a major public health challenge, AI offers a promising pathway toward more precise and personalised care.[19] By addressing existing obstacles—including data quality, privacy concerns, and regulatory gaps—AI has considerable potential to reduce the global burden of diabetes management.[20]

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