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Artificial intelligence in type 1 diabetes mellitus

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Abstract

Type I diabetes is an autoimmune disease in the course of which insulin levels are reduced and hyperglycemia occurs. Treatment options for type I diabetes have changed a lot over time. A large contribution to advances in the field of diabetes treatment has been made by artificial intelligence. Originally, the treatment consisted of multiple finger punctures per day and multiple insulin injections. But now, thanks to artificial intelligence technology, a number of solutions are available including continuous glucose monitors and, based on these, a decision support system. This makes it possible to reduce the number of finger pricks and the frequency of insulin administration. Above that, it makes it possible to tailor the treatment process to the patient, prepare personalized recommendations and respond quickly to changes in serum glucose levels.

Key words: diabetes mellitus, artificial intelligence, endocrinology

1. Introduction

Developments in the field of biotechnology and high-throughput computing are contributing to fast and inexpensive data creation. In 2017. 451 million people worldwide had diabetes, according to the International Diabetes Federation. That number is expected to rise to 693 million citizens in the next 26 years. Both environmental and genetic factors play an important role in the course of diabetes, although the main cause is still unclear (1). Advances in machine learning and the development of artificial intelligence are contributing to earlier detection of diabetes than by manual methods (2). This reduces the risk of human error and decreases the overload on medical personnel. The amount of information accumulated from a diabetes patient is very large and difficult to manage manually, so the use of computer techniques is very helpful in this regard. Nevertheless, even the latest technologies do not fully solve problems such as weight gain or hypoglycemia.

The main purpose of this review paper is to present the possibility of using artificial intelligence in patients with type I diabetes. The authors address both the benefits of this solution, as well as mention the limitations of using artificial intelligence. It is important to regularly summarize the state of the art and keep abreast of scientific developments.

The paper is divided into a general section talking about diabetes and artificial intelligence and a section on the use of artificial intelligence in patients with type II diabetes. Finally, all the collected information is summarized.

2. Background

Normal glucose concentration is maintained by complex signaling pathways, where the most important are insulin and glucagon. Insulin stimulates glucose metabolism while lowering glycemia whereas glucagon acts antagonistically and increases serum glucose concentration. Thanks to these hormones, glucose concentrations are maintained in an optimal range despite circular fluctuations (3).

Type one diabetes mellitus (T1DM) is a chronic autoimmune disease. In the course of type I diabetes, insulin deficiency is observed, resulting in increased serum glucose levels (hyperglycemia), i.e. glucose levels of 160-180 mg/dl (4). In the course of the disease, the immune system attacks the beta cells of the pancreas, which results in abnormal insulin secretion, leading to increased serum glucose levels (5).

The disease can occur at any age; however, it most often affects children and adolescents. It is one of the most common endocrine diseases among children (6). Symptoms include excessive thirst, frequent urination, weight loss and vision problems. Patients must constantly monitor glucose levels and use insulin to maintain optimal glucose levels.

During the course of the disease, antibodies against pancreatic beta cells develop. In contrast, a small percentage of patients do not develop antibodies; this type of diabetes is referred to as T1bDM or idiopathic T1DM. Antibodies may appear several years before the development of the disease, however, this does not directly indicate the onset of the active form of the disease, but may be a marker for the occurrence of the disease in the future (7).

Type I diabetes can be divided into stages, during which antibodies are formed, pancreatic beta cells are destroyed, glucose levels are disturbed and eventually clinical symptoms appear (8).

According to the International Diabetes Federation, up to 8.8% of the population has diabetes, but only 10 - 15% of patients have type I diabetes (9). Type II diabetes is the most common form of diabetes, as it reaches nearly 90%. Type II diabetes is a disease entity affecting adults and is characterized by varying degrees of insulin resistance and impaired insulin secretion (10). The incidence of T1DM is increasing. About 90000 children a year are diagnosed with T1DM (5). This is influenced by both environmental and genetic factors. The disease is most common in Scandinavia, Europe, North America and Australia. In contrast, it is found relatively rarely in Asian countries (11). T1DM is most often diagnosed in adolescents between the ages of 12 - 14.

Treatment of diabetes has changed significantly over the past decades. Originally, treatment consisted of single-dose insulin; today, long-acting and short-acting insulin, specialized insulin pumps and systems that control glucose levels in the body are in use. Some patients, however, opt for multiple finger pricks throughout the day and multiple insulin injections due to conviction or the costs associated with using modern equipment.

3. Artificial intelligence

Artificial intelligence (AI) can be defined as “a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behavior, and with the creation of artifacts that exhibit such behavior" (12). AI is a field of computer science, also capable of analyzing complex data, including medical data (13). AI can play a role in the medical sector in diagnosis as well as treatment (14). Artificial intelligence supports medical professionals on a daily basis in selecting therapeutic processes, predicting recovery or determining diagnosis. Artificial neural network (ANN) is the most widely used solution in medicine (15). It is a computer tool that mimics the nervous system, consisting of multiple interconnected processes capable of performing parallel calculations and presenting data. ANN can learn from previous actions, analyze non-linear data and deal with imprecise data (14). Neural networks have already found wide application because of their ability to analyze and present data. ANNs analyze the complex responses of multiple clinical, biological and pathological variables and predict outcomes. Artificial intelligence in medicine plays a role in diagnosis and prediction of prognosis and the healing process. This technology plays a role in a disease such as type one diabetes, among others (16).

4. Artificial intelligence in type 1 diabetes mellitus

Patients with type I diabetes face many difficulties in monitoring the disease. Proper insulin dosing is essential to maintain glucose levels properly. Fear of hypoglycemia, difficulty counting to calculate glucose meal or correction boluses, changes in insulin sensitivity during exercise, illness, stress and menstruation, and the psychological effects of this chronic disease make it difficult for people with T1D to adhere to prescribed treatment regimens (17). Artificial intelligence plays a role in the management of type I diabetes. Areas of application for artificial intelligence, according to AI:

- Glucose monitoring - AI-based systems are able to collect and analyze data in the context of glucose levels and can send alerts to the patient via receivers, such as smartphones, about changes in glucose levels.
- Insulin management - artificial intelligence can assist insulin pump systems by being able to select insulin dosage based on data such as carbohydrates consumed, physical activity and glucose levels.
- Personalizing treatment regiment and management - by collecting data about the patient including lifestyle and serum glucose levels, artificial intelligence can personalize treatment plans accordingly and adjust accordingly to the patient's changing needs.

- Patient education - artificial intelligence can be used in applications that educate patients about their disease and how to manage it.
- Data analysis - artificial intelligence can collect and analyze large data sets. Such activity can lead to new discoveries and a better understanding of the disease.

Continuous glucose monitors (CGM) is one example of the use of artificial intelligence and an alternative to frequent finger pricking to measure glucose levels. The use of the aforementioned system has increased significantly in recent times (18). The device consists of a small part placed in subcutaneous fat tissue with a miniature needle capable of measuring glucose concentration. The receiver, on by contrast, usually communicates wirelessly with the sensor and gives the patient access to the information at any time. With the CGM, the patient and doctor can continuously monitor the patient's glucose levels, as measurements can be taken as often as every 5 minutes. This gives a detailed insight into the course of the disease and makes it possible to adjust the patient's lifestyle. Moreover, thanks to the use of artificial intelligence, among other things, modern CGMs detect hypoglycemia and hyperglycemia and send special messages to the user's smartphone. CGM additionally has a positive effect on glycated hemoglobin, however, as the only solution, it does not achieve the desired result in all patients (19). Nevertheless, the system cannot eliminate finger pricking one hundred percent, as this is necessary to check the device and verify that the measurements are reliable (20). Above and beyond that, patients, their family and medical staff must be trained in the appropriate use of the CGM and be aware of the limitations of the device (21). Some studies show improved management of type I diabetes (22, 23). while other studies show no significant differences due to CGM use (24, 25). Most sensors have a useful life of 7-14 days, although the FDA recently approved a sensor that can be used for six months (26).

Based on CGM, a decision support system (DSS) has been developed, which are applications that provide precise recommendations to patients. Artificial intelligence, by analyzing collected data, learning and using previously gathered information, allows the development of advice for patients and makes it possible to reduce the frequency of visits to the doctor. In addition, AI-based systems allow better prediction and prevention of possible hypoglycemia. DSSs also enable assistance with carbohydrate counting, visualize data and provide diabetes education (27). Furthermore, DSSs support the adjustment of insulin therapy and the use of short-acting and long-acting insulin. An effective DSS reduces the time spent in hypoglycemia or optimizes and extends the time with a patient's normal glucose levels. The benefits associated with the use of DSS are measured against either self-reported standards or against a control group that does not use DSS.

Apps for patients with type I diabetes carry some limitations. Recent studies indicate that of the hundreds of apps available, only 12 have adequate validation and only a few have improved glycated hemoglobin (HbA1c) levels (22, 23, 28, 29). Another problem is data collection. Indeed, AI systems rely on large amounts of data for learning, which can be difficult to collect for various reasons. Moreover, there is the factor of variability in the progression of the disease, which can vary greatly from one individual to another. This can make it difficult for AI to make appropriate recommendations taking into account differences among patients. Another limitation is the complexity of insulin dosing with factors such as diet, exercise, stress and menstruation. AI systems may have difficulty taking all variables into account and selecting recommendations based on this. Finally, another limiting factor may be the technology used in the implementation of a given system. Limitations arise from inaccurate measurements and, based on this, erroneous AI recommendations (30).

5. Conclusion

The treatment of type I diabetes is a major challenge from the diagnosis itself, through data collection and management to treatment. The growing number of patients is making this problem more frequent. AI and ANN-based technology is helpful in this regard. It enables the collection, storage and analysis of huge amounts of data on the basis of which the doctor and patient get precise guidelines for diagnosis, treatment and lifestyle. AI is also involved in the development of science and the emergence of new technologies for type I diabetes. In summary, AI plays an important role in the management of type I diabetes, thanks to its ability to collect and analyze data, create guidelines, assist patients and formulate conclusions based on large databases.

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