Errors in the diagnosis of types of diabetes mellitus: causes and prevention strategies (literature review and own research results)

Abstract. The article provides current information regarding medical errors in diagnosing diabetes mellitus (DM), analyzes their factors, and outlines preventive measures. The causes of the most common diagnostic errors in diabetology include limited access to quality healthcare, insufficient training and number of qualified personnel, low quality of teamwork and medical information exchange, inadequate availability of diagnostic tests, poor coordination of care and follow-up, lack of medical informatics resources, human factors, and cognitive biases (such as misidentification of DM and its type, incorrect context creation, overestimation/underestimation of incidental findings, premature termination of the diagnostic process, and lack of knowledge and skills in diabetology). The most typical diagnostic discrepancies involve misidentifying type 1 DM (including latent autoimmune diabetes in adults), type 2 DM, and other specific types of DM. This is due to the increasing heterogeneity of DM, blurring of the boundaries between its types, atypical disease course, the decreased diagnostic value of the essential criteria for DM types (age, presence of metabolic syndrome signs, ketosis, dependency on insulin therapy), presence of comorbid conditions, and limited availability of diagnostic tests to specify the type of diabetes. To optimize diagnosis and prevent diagnostic errors, we have developed a Telegram bot DiaType based on a multilevel algorithm for the differential diagnosis of various types of DM. The testing of this Telegram bot has shown its high effectiveness in identifying DM variants. The advantages of DiaType include accessibility, interactivity, accuracy, and support for medical professionals, which helps improve diagnostic efficiency, simplify the diagnostic process, especially for primary care physicians, prevent diagnostic errors, and, consequently, improve treatment outcomes.

Keywords: diabetes mellitus; types; heterogeneity; diagnosis; medical errors; informational technologies; chatbot
systems. These factors can lead to a higher frequency of diagnostic errors [3].

Recently, there has been an increase in the diversity of diabetes mellitus (DM) manifestations, complicating the clear delineation of its forms. The disease increasingly presents in atypical variations, leading to a decrease in the relevance of traditional diagnostic criteria for DM types, such as the patient’s age, presence of metabolic syndrome, insulin dependence, etc. There is an underdiagnosis of other specific types of diabetes. The situation is further complicated by the limited availability of diagnostic tests to clarify the type of DM. This leads to errors in diagnosing DM types and incorrect patient management strategies [5–7].

According to the modern classification proposed by the American Diabetes Association (ADA), there are four classes of DM based on etiology [8]:

— type 1 diabetes mellitus (T1DM). This type is caused by autoimmune destruction of the β-cells in the pancreas, usually leading to an absolute insulin deficiency. It also includes latent autoimmune diabetes in adults (LADA);
— type 2 diabetes mellitus (T2DM). This type is characterized by a gradual loss of adequate insulin secretion by β-cells against a background of insulin resistance;
— specific types of diabetes mellitus. These types arise from other causes, such as monogenic diabetes syndromes (neonatal diabetes and maturity-onset diabetes of the young (MODY)), exocrine pancreas diseases (cystic fibrosis, pancreatitis), and drug- or chemical-induced diabetes (from glucocorticoid use, HIV/AIDS treatment, or organ transplantation);
— gestational diabetes mellitus. This type is diagnosed during the second or third trimester of pregnancy and was not present before gestation.

Traditional views of T1DM and T2DM, where the former is associated with children and the latter with adults, have lost relevance, as both types of the disease are diagnosed across different age groups. In adults, the onset of T1DM can be more varied: they may not exhibit the classic symptoms seen in children and sometimes may even experience temporary remission without the need for insulin administration [9]. Sometimes, patients with T2DM can also develop diabetic ketoacidosis and other complications [10].

Experts from the ADA note that classifying diabetes mellitus by type can be complex, and incorrect diagnoses are often made in the early stages of treatment. For example, adults with T1DM may be mistakenly diagnosed with T2DM, and MODY in mature individuals is frequently misclassified as T1DM [8]. Incorrect diagnosis can have severe consequences for patients. Treatment that does not correspond to the actual type of DM may lead to ineffective blood glucose control, development of complications, and deterioration in quality of life. All of this underscores the need to develop approaches to improve the quality of diagnosis in diabetology.

**Diagnostic errors**

Diagnosis typically occurs over some time and involves initial assessment, performance and interpretation of diagnostic tests, ongoing monitoring, tracking of diagnostic information, communication and coordination related to referrals, as well as patient behavior and compliance. Diagnostic errors can occur at each of these stages [11]. Diagnostic errors are the inability to provide accurate and timely explanations of a patient’s health problems or to communicate these explanations to the patient [12]. They are considered missed opportunities to establish the correct or timely diagnosis based on available evidence, which can be caused by cognitive or systemic factors or their combination [13].

**Types of diagnostic errors.** A diagnostic error occurs when: 1) a diagnosis is not established; 2) a diagnosis is established, but not on time; 3) a diagnosis is established, but is incorrect [14]. Indeed, diseases can be missed (diabetes mellitus not detected despite symptoms), misdiagnosed (informing a patient of one type of diabetes mellitus when there is evidence for another), or diagnosed untimely (not telling a patient of test results indicating diabetes mellitus). It’s also possible to have a combination of these situations [4].

**Causes of diagnostic errors.** Accurate and timely diagnosis depends on various factors, including the knowledge, experience, and skills of medical personnel and the availability of resources. It is a high-risk area for medical errors, especially among primary care physicians who typically treat many patients. The conditions they encounter often have complex clinical presentations, making diagnosis challenging [15]. Additionally, physicians may have limited experience regarding rare pathologies or unusual presentations of diseases, and there may be variability in access to diagnostic tests.

**Overall factors**

Many reasons can contribute to the occurrence of diagnostic errors [1].

**Access to quality primary healthcare.** Limited access to primary and specialized healthcare can be due to financial difficulties, distance from medical facilities, low levels of health literacy, transportation issues, or a shortage of medical facilities. This can lead to underdiagnosis and incorrect diagnosis of DM.

**Availability of healthcare workers and specialists.** Insufficient number of qualified healthcare workers may be related to a lack of training, migration of medical personnel, or adverse working conditions. A limited number or low quality of specialists in the field of diabetology can contribute to errors in the diagnosis and treatment of diabetes.

**Teamwork.** Poor quality teamwork, lack of training, and lack of feedback after errors can negatively impact the diagnostic process. This can lead to misinterpretation of diabetes symptoms and incorrect diagnosis.

**Availability of diagnostic tests.** Limited volume, availability, or quality of diagnostic tests, such as blood glucose tests, glycated hemoglobin (HbA1c) tests, and other specific tests, can complicate the accurate diagnosis of DM.

**Communication.** Low levels of medical information exchange among healthcare workers can lead to incomplete or incorrect interpretation of patient data, complicating the correct diagnosis of diabetes.

**Care coordination.** Delays in consultations, loss of test results, and absence of medical records can hinder the timely and accurate diagnosis of diabetes.

**Follow-up care.** Limited follow-up care for patients reduces the ability to adjust the diagnosis and treatment of DM based on changes in the patient’s condition or new test results.
Access to healthcare. Inaccessibility of healthcare or lack of other basic needs, such as food or housing, can lead to missed diagnostic opportunities and complications in patients with diabetes.

Medical staff training. Inadequate training of healthcare professionals in diabetology and deficiencies in certification and licensing can contribute to diagnostic errors when determining the type of diabetes.

Availability of medical informatics resources. Lack of access to medical informatics resources, including the internet, especially in remote areas, and issues with accessing medical information can limit physicians’ knowledge and opportunities for correct diagnosis of diabetes.

Culture. Culture plays a significant role in the occurrence of diagnostic errors as it influences the perception, interpretation, and evaluation of information. Cultural differences can lead to misinterpretation of symptoms, incorrect interpretation of behavior, or deviations from norms, resulting in errors in diagnosis and treatment. Additionally, cultural perceptions of normalcy and pathology may vary, necessitating consideration of cultural contexts in diagnosis.

Human factors and cognitive issues. Work environments prone to distractions, interruptions, and lack of information organization can lead to diagnostic errors. This is especially critical in cases of diabetes, where diagnostic accuracy is crucial for further treatment.

Diabetes-specific factors

Diagnosing different types of diabetes is a complex and critical task in medicine. Incorrect diagnosis can lead to inadequate treatment, worsening the patient’s condition. Each type of diabetes has its characteristics and requires a specific approach to treatment. However, several factors can contribute to errors in diagnosing these types of diabetes [17].

Genetic and epigenetic factors. Genetic mutations and epigenetic changes can affect gene expression, leading to various forms of diabetes. For instance, monogenic forms of diabetes are often misdiagnosed as T1DM or T2DM due to symptom similarity. This happens because of insufficient awareness and testing for rare genetic mutations.

Behavioral and environmental factors. Behavioral factors, such as diet and physical activity levels, as well as environmental influences, can significantly alter the manifestations of diabetes. For example, poor diet and a sedentary lifestyle can contribute to the development of T2DM, but in some cases, these factors can mask the symptoms of T1DM, especially in adults.

Comorbidities. Comorbid conditions, such as chronic pancreatitis or pancreatic cancer, can lead to type 3c diabetes (pancreatogenic diabetes). This type of diabetes is often misdiagnosed as T1DM or T2DM because the clinical manifestations can be similar, though the disease’s etiology is different.

Technical errors in diagnosis. Technical errors include diagnostic approaches (lack of clear protocols or the use of outdated methods can cause misdiagnosis), observer errors (subjectivity of the doctor, inexperience, or failure to consider all symptoms can lead to mistakes), analytical errors (incorrectly conducted tests or technical equipment failures), and stochastic errors (random errors that occur during the diagnostic process). For example, incorrectly performed laboratory tests or errors in interpreting results can lead to a false diagnosis.

Role of cognitive biases

In today’s world, the study of cognitive biases — unconscious errors in human thinking that occur when processing and interpreting information and affect subsequent decision-making — is becoming increasingly popular. They account for 74% of all errors [18] and mainly arise due to incorrect synthesis, data collection, and erroneous knowledge. Clinical thinking is the process of analysis and decision-making in the medical field. In other words, the physician can conclude and make decisions based on available information to achieve the best outcomes for the patient [19].

According to a recent prospective international study, seven of the most common medical errors and cognitive biases in the field of endocrinology have been identified: incorrect identification of nosology, improper context creation with omission of important information, premature closure of the diagnostic process, lack of knowledge in a specific medical area, erroneous triggering, overestimation or underestimation of data, and lack of diagnostic skills [20].

Incorrect identification. This error occurs when a doctor mistakenly identifies one type of diabetes as another, e.g., T2DM as T1DM or vice versa. It can happen due to similar clinical signs and symptoms, such as elevated blood glucose levels.

Improper context creation. In this case, the doctor considers important clinical signs like hyperglycemia or family history, but fails to account for specific test results (C-peptide levels or antibodies to islet antigens). This leads to an incorrect diagnosis because the data collection was completed, but the interpretation was inaccurate.

Premature closure. The error of premature closure occurs when a doctor does not verify all necessary diagnostic data and makes conclusions based solely on initial symptoms or history. For example, if a patient has symptoms of hyperglycemia, but the doctor does not conduct additional tests to determine the type of diabetes, the diagnosis may be incorrect.

Lack of knowledge. This type of error occurs when a doctor does not know which test results are pathological for different types of diabetes. For instance, a doctor might not know that a low C-peptide level indicates T1DM, but it is also characteristic of MODY and pancreatogenic diabetes, leading to incorrect interpretation of results.

Erroneous triggering. This error occurs when a doctor reviews all critical information and correctly interprets diagnostic tests, but still makes an incorrect diagnosis. For example, a doctor might correctly identify the absence of autoimmune markers, but, due to other factors, mistakenly diagnose T2DM instead of MODY.

Overestimation/underestimation. A doctor gives excessive importance to a particular finding, such as the presence of ketosis, and makes a diagnosis of T1DM based on it. Alternatively, the doctor might underestimate a vital sign, like an average C-peptide level.

Lack of diagnostic skills. This error occurs when a doctor incorrectly interprets the results of technical examinations,
including laboratory tests. For example, a doctor might miss important signs of pancreatogentic diabetes.

The authors note that although errors in clinical reasoning continue to be a prevalent issue, frequently due to deficiencies in knowledge and skills, other common mistakes in communicating test results and conducting follow-ups necessitate distinct strategies for improvement, such as upgrading technological systems [16].

Errors can arise when minor clinical symptoms of a disease are missed or ignored at the primary level. These errors can significantly impact the accurate diagnosis of diabetes types, leading to incorrect treatment and complications. To reduce the number of such errors, it is necessary to improve diagnostic methods, increase doctors’ awareness, and provide them with the necessary knowledge and skills.

**Diabetes heterogeneity as a factor in diagnostic errors**

As noted earlier, there has been an increase in the heterogeneity of DM, which has blurred the lines between its types. The disease increasingly presents atypically, reducing the relevance of traditional diagnostic criteria for diabetes types.

The most pressing diagnostic issue in diabetology is distinguishing between T1DM and T2DM. These two categories have different etiologies and require different treatment methods. Diagnosis is complicated because T1DM and T2DM are not homogeneous, and “gold standard” diagnostic criteria are not universally accepted. Problems arise when clinical signs do not match expectations (for example, young patients with obesity or older patients with average weight, or patients with rare diabetes subtypes) [22].

Combinations of different types of diabetes (double or even triple) are also becoming more common. In the 2019 classification by the World Health Organization, they are referred to as “hybrid” forms of diabetes [23]. These atypical variants of diabetes can be challenging to diagnose and treat, as their clinical presentation can be highly diverse and variable. The most notable example of “hybrid” diabetes is LADA, which is characterized by a less active autoimmune process and a wide range of clinical signs compared to classical T1DM and can exhibit features of both major types of diabetes [24, 25].

Various pathophysiological processes contributing to the risk and progression of diabetes, with variable relative importance in each individual, define the phenotype and can be used for therapy [26]. The threshold hypothesis posits that the clinical manifestation of diabetes develops when the combined influence of genetic and environmental factors exceeds a certain threshold. These models can be integrated to understand the combined effect and interaction of various diabetes risk factors in different individuals, supporting the search for endotypes that help clarify the heterogeneity within diabetes types and optimize therapeutic approaches [27].

Genetic factors and environmental influences, along with their interactions, affect numerous mechanisms (autoimmunity, beta-cell mass reduction, insulin secretion defects, inflammation, healthcare barriers) that can variably contribute to the development and progression of diabetes in each patient. This individual variability leads to heterogeneity within and between diabetes types (e.g., very early-onset T1DM, LADA) [5].

Given the newly disclosed aspects of pathophysiology and clinical manifestations of carbohydrate metabolism disorders, some researchers have proposed a new diabetes classification based on clustering by different features.

Based on leading characteristics, such as age at disease manifestation, body mass index (BMI), presence of glutamic acid decarboxylase (GAD) autoantibodies, glycated hemoglobin (HbA1c) levels, insulin resistance index (HOMA2-IR), and basal beta-cell secretion (HOMA2-β), five clusters of this disease have been proposed: severe autoimmune diabetes (SAID), severe insulin-deficient diabetes (SIDD), severe insulin-resistant diabetes (SIRD), mild obesity-related diabetes, and mild age-related diabetes [28].

The first cluster (SAID) includes young patients with low BMI, poor glycemic control, high titers of GAD autoantibodies, high HbA1c levels, and a significant decrease in the HOMA2-β. In the World Health Organization classification, SAID corresponds to T1DM. The second cluster (SIDD) is similar to the first in characteristics, but without GAD autoantibodies. Patients with SAID and SIDD are prone to complications, such as ketoacidosis and diabetic retinopathy. The third cluster (SIRD) comprises individuals with high BMI and HOMA2-IR, often diagnosed with reduced glomerular filtration rate, increasing the risk of developing microalbuminuria and chronic kidney disease. Patients with SIRD also have a higher frequency of non-alcoholic fatty liver disease. The fourth cluster (mild obesity-related diabetes) consists of individuals with high BMI, a moderate increase in the HOMA2-IR, and a slight decrease in the HOMA2-β. The fifth cluster (mild age-related diabetes) includes elderly patients with stable diabetes course and normal HOMA2-IR. Such a precise approach allows for the timely prescription of pathogenetic treatment and predicting the development of chronic diabetes complications [28, 29].

**Atypical forms of diabetes**

Atypical presentations are increasingly recognized as significant contributors to diagnostic errors. Many patients may have a form of diabetes that does not quite fit the diagnosis of T1DM or T2DM. The discovery and description of these variants of “atypical diabetes” significantly contributed to understanding the basic biology governing insulin secretion, insulin resistance, and islet autoimmunity. Atypical diabetes is suspected in individuals who do not clearly fit the current criteria of T1DM, T2DM or secondary diabetes. In this regard, endotypes have been proposed, where patients with diabetes can be clustered based on similar clinical or molecular-genetic mechanisms [30].

The Rare and Atypical Diabetes Network has been developed to characterize unusual subtypes of diabetes and identify new mechanisms or causal pathways that can be used for prevention or treatment [31].

According to scientists, the analysis will help improve the means of identifying atypical diabetes. Genetic sequencing can reveal new variants, while metabolomic and transcriptomic analysis can identify new mechanisms and biomarkers of atypical disease. The main forms of atypical diabetes known at the moment are [32]:

— monogenic diabetes. Diabetes caused by a mutation in a single gene. It is often found in children and young adults and has various forms, including MODY;
— syndromic diabetes. Diabetes that is part of a genetic syndrome, which includes other physical or mental anomalies, such as Wolfram syndrome or Beckwith-Wiedemann syndrome;
— mitochondrial diabetes. Arises from mutations in mitochondrial DNA, often associated with other symptoms, such as deafness;
— lipodystrophies. Rare disorders where fat tissue is absent or improperly distributed, leading to insulin resistance and diabetes;
— insulin resistance syndromes. A group of disorders when tissues become less sensitive to insulin, leading to elevated blood glucose levels. Examples include polycystic ovary syndrome and Cushing’s syndrome;
— ketosis-prone diabetes with positive antibodies and preserved β-cell function;
— ketosis-prone diabetes with negative antibodies and preserved β-cell function;
— ketosis-prone diabetes with negative antibodies and lost β-cell function;
— pancreatogenic diabetes. Diabetes that arises from diseases of the pancreas, such as chronic pancreatitis, pancreatic cancer, or after pancreactectomy;
— fulminant diabetes. A rare form of diabetes characterized by sudden and very rapid development of hyperglycemia and ketosis with complete loss of β-cell function;
— LADA. Slowly progressing autoimmune diabetes in adults, often initially diagnosed as T2DM;
— slowly progressing autoimmune diabetes. A form of T1DM that develops slowly and may manifest in adulthood, but has an autoimmune nature;
— insulin-deficient diabetes without obesity. Diabetes that develops in individuals with normal or insufficient body mass, but with insulin deficiency.

It is expected that the assessment of different endotypes associated with atypical diabetes will increase the accuracy of diagnosis and facilitate making targeted treatment decisions.

**Ways to prevent diagnostic errors**

To prevent diagnostic errors, the ADA and the EASD have developed a new approach called precision diabetology, which aims to explore new opportunities to improve the diagnosis of diabetes [17, 33].

**Precision diagnosis.** Precision diabetic medicine is an approach to optimize the diagnosis, prognosis, prevention, or treatment of diabetes by integrating multidimensional data while considering individual differences. Precision diagnosis involves refining the characterization of the diabetes diagnosis for therapeutic optimization or improving prognostic clarity using information about the individual’s unique biology, environment, and/or context. Accurate diagnosis may include classifying the diagnosis into subtypes, as in case of MODY, or using probabilistic algorithms to refine the diagnosis without categorization [34].

A thorough diagnosis is often necessary for successful precise therapy for prevention and treatment. Accurate diagnosis can be conceptualized as a process rather than a single step. The stages of diagnosis include: 1) prevalence assessment based on epidemiology, including age or age at diabetes diagnosis, gender, and ethnicity; 2) probability based on clinical features; 3) diagnostic tests interpreted in light of the first two stages. Diagnosis in precision medicine is a probability-based decision, typically made at a specific point in the natural course of the disease and is neither an absolute truth nor a permanent state [33].

**Other necessary measures to avoid diagnostic errors** include [7, 35, 36]:
— increasing physicians’ awareness of different types of diabetes and their specific manifestations;
— utilizing modern diagnostic methods involves implementing new genetic tests and improved laboratory techniques;
— developing clear protocols, including establishing standards for diagnosing and treating different types of diabetes;
— adopting a multimodal approach, which involves using a combination of clinical, laboratory, and genetic data for precise determination of diabetes type.

**Leveraging information technologies.** Recently, there has been extensive discussion about the potential use of information technologies (IT) in diabetology, particularly to avoid diagnostic errors in diabetes typing.

Scientists highlight the main directions for using IT to help prevent diagnostic errors [37].

**Facilitating information gathering.** Information systems provide access to previous medical records and patient data, helping gather crucial clinical information. For example, systems can automatically remind physicians to inquire about a family history of diabetes and lifestyle factors (e.g., smoking and physical activity). Triggers can also be used to detect patients with suspected diagnostic errors, such as the wrong type of diabetes.

**Optimizing organization and data display.** IT systems reduce the cognitive load on physicians by highlighting important information to avoid oversight. This includes crucial clinical indicators and other diagnostic results that may indicate the type of diabetes.

**Creating a broad diagnostic spectrum.** Technologies offer key questions or tests for consideration using differential diagnosis generators. This helps physicians avoid hasty conclusions and consider all possible types of diabetes.

**Assessing diagnostic probabilities.** IT systems combine clinical data with diagnostic test results to calculate the probability of a specific type of diabetes. This facilitates the use of clinical prediction rules to improve diagnostic probability assessment, taking into account risk factors and symptoms.

**Developing a diagnostic plan.** Technologies streamline the process of planning the next steps by providing standard sets of tests and guidance. For instance, the system can flag patients with an unclear disease course and automatically suggest relevant additional tests to refine the diagnosis.

**Providing access to reference materials.** IT systems grant physicians access to information, journals, images, and clinical guidelines that can help diagnose and treat various types of diabetes.

**Continued patient monitoring.** Systems support a systematic approach to continued patient monitoring. Reminder tools can alert healthcare providers about the need for further screenings or check-ups for diabetic patients, helping prevent complications.
Support for screening programs. IT systems enhance compliance with screening programs through automatic reminders and reports. This helps identify patients at high risk of diabetes and those who have fallen out of the medical system’s radar.

Providing tools for collaborative diagnosis. IT technologies facilitate access to expert opinions and make it easier to involve colleagues in discussing complex cases through telemedicine or electronic consultations, which is particularly important in diagnosing rare types of diabetes.

Feedback support for physicians. Technologies establish a clear chain of events with more precise documentation of the assistance process. Identified errors can be relayed back and used as a learning experience for all medical practice participants.

Detection of diagnostic errors. Double-checks using electronic algorithms can identify missed diagnostic opportunities and discrepancies, especially in diagnosing types of diabetes, allowing timely detection and correction of errors.

Facilitating practice improvement research. IT systems generate epidemiological data and comparisons between healthcare providers, clinics, or regions to investigate differences in patient outcomes and negative events associated with possible diagnostic errors.

Utilizing artificial intelligence. Evidence is emerging of the effectiveness of using artificial intelligence to prevent diagnostic errors in medicine, significantly expanding diagnostic capabilities in diabetology [38, 39].

It’s essential to consider that the use of artificial intelligence in medicine requires careful attention to ethical, confidential, and security issues. It cannot replace the human knowledge, empathy, and clinical experience of a physician, but it can serve as a powerful tool to support decision-making and improve the quality of diagnosis in medical practice. It’s also worth noting that the current version of ChatGPT can be helpful for medical personnel; however, researchers are advised to fact-check all provided statements, keeping in mind their limitations [40].

Results
Our research aimed to optimize the diagnosis of different types of diabetes and prevent diagnostic errors. To achieve this, we decided to develop a chatbot based on a multilevel algorithm for the differential diagnosis of various types of DM.

In the initial stage we conducted a thorough investigation based on literature data and our own clinical observations. We examined the most typical variants and reasons for discrepancies in diagnoses when identifying types of diabetes. Following the modern recommendations of leading diabetic societies and expert groups, we compiled a detailed list of complaints, medical history data, and results of objective, laboratory, and instrumental studies characteristic of different types of DM [8, 41–43].

In our search for a suitable program, we chose a chatbot. A chatbot is a computer program developed based on neural networks and machine learning technologies, allowing communication in audio or text format. It’s an artificial intelligence program that simulates an interactive conversation with a human using predefined key phrases from the user. Chatbots can conduct preliminary interviews and provide recommendations for further actions based on this. They can automatically collect and analyze patient data, creating a detailed patient profile to assist doctors in making an accurate diagnosis. Using machine learning algorithms, chatbots can analyze symptoms and clinical data, for example, to preliminarily determine the probable diabetes type.

For broader and more convenient use we chose to develop a Telegram bot. By employing formalization and systematization methods with the multichannel automation platform SendPulse [44], we created a Telegram bot DiaType.

DiaType creation technologies. DiaType bot was developed using SendPulse auto-replies and behavioral pipelines. It utilizes a multilevel differential diagnosis algorithm, implemented with specialized rating and classification tables.

The main stages of creating DiaType are illustrated in Fig. 1.

![Figure 1. The process of creating a Telegram bot DiaType](image-url)
In the first stage, an interactive mode collects complaints, medical history, and available examination results. A chatbot adapts questions to each specific patient. Based on the received answers, DiaType formulates a preliminary version regarding the type of DM and recommends further examination if necessary. After recording the results of these examinations, DiaType determines the most likely diagnosis.

Fig. 2 illustrates the work of a Telegram bot DiaType when diagnosing diabetes type at the initial stage (A) and in a patient with suspected LADA (B), who was diagnosed with T1DM, along with a list of recommended laboratory tests to confirm the diagnosis.

The preliminary testing of DiaType has demonstrated its high accuracy and effectiveness in diagnosing diabetes types. It has been found that it facilitates better collection and analysis of medical data, provides advice for further actions, and supports healthcare professionals in decision-making. Its advantages include accessibility (a bot is available anytime and anywhere, simplifying diagnosis), interactivity (users can interact with a bot in a convenient format), accuracy (the use of a multilevel algorithm increases diagnostic accuracy), and support for medical professionals (a bot can be particularly useful for primary care physicians, providing them with tools for better diabetes type recognition).

We believe a Telegram bot DiaType could become an important tool in improving the quality of medical care for patients with diabetes.

Conclusions

Thus, the leading causes of diagnostic errors in diabetology include limited access to quality medical care, insufficient training and number of qualified personnel, poor teamwork and medical information exchange, inadequate availability of diagnostic tests, poor coordination of care and monitoring, lack of medical informatics resources, human factors, and cognitive biases. Typical diagnostic errors include incorrect determination of the type of DM (especially T1DM, T2DM, LADA, MODY, diabetes 3c), which is due to the increasing heterogeneity of the disease, blurring of boundaries between its types, atypical course, decreased diagnostic value of classical criteria, comorbid conditions, and low availability of diagnostic tests. A Telegram bot DiaType, created based on a universal multilevel diagnostic algorithm, increases the accuracy and effectiveness of diagnosis, simplifies the process for primary care professionals, helping to prevent diagnostic errors and improve treatment outcomes.

References


Помилки в діагностиці типів цукрового діабету: причини і шляхи запобігання (огляд літератури та результати власних досліджень)

Резюме. У статті наведено сучасні відомості щодо лікарських помилок у діагностиці цукрового діабету (ЦД), проаналізовано їхні чинники, окреслено шляхи запобігання. Принципами найбільш поширенних діагностичних помилок у діабетології є обмежений доступ до якісної медичної допомоги, недостатня підготовка та кількість кваліфікованих кадрів, низька якість командної роботи, обміну медичною інформацією, недостатня доступність діагностичних тестів, незадовільна координація діагностичного процесу, брак знань і навичок у галузі діабетології. Науково-педагогічні ресурси медичної інформатики, людські фактори та соціальні упередження (зокрема, помилки ідентифікації ЦД і його типу, неправильне створення контексту, переоцінка/недооцінка випадкової знахідки, перезавантаження діагностичного процесу, брак знань і навичок у галузі діабетології). Науково-педагогічні ресурси медичної інформатики, людські фактори та соціальні упередження (зокрема, помилки ідентифікації ЦД і його типу, неправильне створення контексту, переоцінка/недооцінка випадкової знахідки, перезавантаження діагностичного процесу, брак знань і навичок у галузі діабетології). Науково-педагогічні ресурси медичної інформатики, людські фактори та соціальні упередження (зокрема, помилки ідентифікації ЦД і його типу, неправильне створення контексту, переоцінка/недооцінка випадкової знахідки, перезавантаження діагностичного процесу, брак знань і навичок у галузі діабетології). Науково-педагогічні ресурси медичної інформатики, людські фактори та соціальні упередження (зокрема, помилки ідентифікації ЦД і його типу, неправильне створення контексту, переоцінка/недооцінка випадкової знахідки, перезавантаження діагностичного процесу, брак знань і навичок у галузі діабетології).

Ключові слова: цукровий діабет; типи; гетерогенність; діагностика; лікарські помилки; інформаційні технології; чат-бот