

ADVANCES IN PRECISION MEDICINE APPROACHES FOR TYPE 2 DIABETES MANAGEMENT: A COMPREHENSIVE REVIEW

ABSTRACT

Projections indicate that, approximately 700 million people will be living with diabetes by 2050, a figure that has doubled in the previous twenty years. The rising cost of type 2 diabetes care might be reduced and existing treatment gaps could be closed with the help of precision medicine. Taking into consideration each individual unique genetic, environmental, and behavioral characteristic, precision medicine is a new approach to treatment. The primary goal of precision medication is to accurately foresee how a patient will respond to treatment. It may be used as a prophylactic strategy for the whole population because of how broadly it applies. Medication, weight reduction, regular exercise, and a nutritious diet all work together to prevent type 2 diabetes. Optimizing metabolic control is one way in which this kind of diabetes therapy has a probability to reduce death rates and improve standard of life. Inadequate funding for translational health research, incompatible data formats, a lack of system interoperability, a lack of decision-making support systems, and a lack of IT infrastructure support are just some of the obstacles to the widespread utilization of precision medicine technologies in clinical practice. Forecast translation of scientific results into practical applications may be aided by the creation of a worldwide clinical studies group dedicated to raising public understanding and appreciation of the great advantages of precision medicine in treating diabetes.

KEYWORDS: Precision medicine, Diabetes, Management, Omics, Approach

INTRODUCTION

More than 463 million people throughout the world are living with diabetes, making it one of the most widespread health problems of the 21st century. Projections indicate that, there will be approximately 700 million people living with diabetes by 2050, a figure that has doubled in the previous twenty years(1). Socioeconomic, demographic, environmental, genetic, urbanization, and lifestyle changes all have a role in the rising incidence (2). It is predicted that during the next quarter century, the middle-income nations would bear the brunt of the worsening worldwide diabetes treatment gap (2). Hyperglycemia during pregnancy, an increase in the genetic susceptibility for diabetes during infancy and adolescence, a lack of access to drugs, and a lack of access to health care are all factors that contribute to these disparities (3). Given that individuals with diabetes account for \$760 billion (USD) annually, or 10% of global health expenditures, the rise in diabetes incidence and disparities is a global concern(4). Medical care for those with diabetes is estimated to cost 2.3 times that of people without diabetes in the United States (4). Moving toward precision medicine has the ability to stabilize diabetic care costs and eliminate disparities in treatment.

DIABETES

Diabetes is caused by high blood glucose levels, also known as high blood sugar levels (5). It occurs when either the body has trouble making or using insulin, the hormone responsible for regulating blood glucose levels. Abnormalities in insulin production, insulin action, or both are what cause hyperglycemia, a metabolic illness (5).

Uncontrolled glucose levels may lead to long-term harm to the cardiovascular system, kidneys, eyes, nerves, and blood vessels. Diabetic complications can lead to a host of permanent health issues, including amputations, renal failure, cardiovascular disease,

and blindness (6). Consequently, it is typically necessary to rely on a treatment regimen consisting of many medications or insulin. Mono-therapy and/or insulin is required for optimum glucose control (6), since uncontrolled glucose levels hasten the progression of type 2 diabetes, increasing the chance of morbidity alongside death.

It is estimated that every year 1.5 million people die from diabetes (7), the vast majority of whom live in developing countries. Ninety percent of diabetics have type 2 diabetes, while the remaining eleven percent have type 1, which often appears between the ages of four and six, and then again between ten and fourteen. Untreated instances of diabetes place an increasing financial and emotional burden on patients' loved ones and the society at large (8) due to the disease's difficulty in management.

Due to the fact that glucose levels have been used almost exclusively for diabetes diagnosis during the last century (9), the present categorization of the two kinds of illness is flawed. Identical to the genetic diagnosis in monogenic diabetes, such as "Maturity-Onset of Diabetes in the Young (MODY)," better diabetes categorization may benefit in accelerating the diagnosis with precision medicine, enabling clinicians to prescribe more effective treatment programs sooner. The opportunity for more specific therapy exists when the differences between these two categories of diabetes are recognized (10). Genetic and phenotypic differences between type 2 diabetes and gestational diabetes have been shown (11).

CLASSIFICATION OF DIABETES

Insulin resistance or inadequate use of insulin (12) is the root cause of both type 1 and type 2 diabetes. It is possible to classify diabetes in a wide variety of ways according to additional criteria, such as in cases of neonatal diabetes, congenital diabetes, drug-induced diabetes, MODY, and secondary diabetes connected with primary endocrinopathies (13).

The simplistic categorization of diabetes into type 1 and type 2 fails to take into account the many ways in which patients' health, response to therapy, and drug side effects interact. Deutsch et al. 2022 classified their patients into six subgroups based on age at diagnosis, homeostatic model assessment estimates of cell function (HOMA2-B) and insulin resistance (HOMA2-IR), antibodies to glutamate decarboxylase (GAD65), body mass index (BMI) and glycated hemoglobin (HbA1c). Type 2 diabetes may range from autoimmunity, insulin deficit, and insulin resistance to moderate obesity-related diabetes and mild age-related diabetes (14, 15).

Pathophysiology of diabetes is complex, making its difficult for interpretation (16). Sub-phenotypes of diabetes may exist, each with its own set of defining features at the molecular level as well as its own pathophysiological processes, complications, and risk factors (16). Medication therapy, providing high-quality care, and self-supervision are three methods that might alter clinical results. Environmental and genetic variables interact to affect pathophysiological procedures such as cell transformation and survival and insulin secretion and action (17). Alpha cells, which produces glucagon, and beta cells, which secrete insulin, make up the endocrine system. It is well-documented that these cells regulate hormone release in accordance with the surrounding glucose environment (18).

Hyperglycemia (12) is caused by diabetes due to the fact that the body either does not produce enough insulin or is resistant to the effects of insulin.

TYPE 2 DIABETES MELLITUS

The etiology of type 2 diabetes is thought to be multifactorial, involving intricate interplay between an individual's genetic predisposition as well as environmental factors (19). The present comprehension regarding the specific mechanisms by which genetic predispositions interact with environmental factors to induce illness is limited

(19). The genetic susceptibility to this kind of diabetes has been studied using a number of surrogate indicators of insulin resistance. Fasting insulin, glucose during the first two hours of an oral glucose tolerance test, glycated hemoglobin, and insulin sensitivity are all examples of such parameters (20). Its rate has risen in both developed and developing nations over the past thirty years.

Annually, over 1.5 million individuals succumb to diabetes, with the majority of fatalities occurring in countries with low to middle income (21). The incidence and prevalence of diabetes have reached unprecedented levels (22). Individuals with diabetes require accessible and cost-effective treatment options, with a particular emphasis on insulin. The escalating prevalence of diabetes and obesity has prompted the global community to pledge a halt to this trajectory by 2025 (7).

Researchers have provided valuable insights into the pharmacologic characteristics associated with genes connected in various steps as well as behaviors linked to each type. These insights can be utilized for precise categorization of individuals (19, 23, 24). Implementing precision medicine for diabetes control requires a thorough understanding of the complicated interaction among these genetic variables. The vast majority of people with diabetes need the usage of various anti-diabetic drugs, since literature shows that pharmacologic treatment for type 2 diabetes evokes a varied range of responses (25.)

While promising, practical use of pharmacogenetics to type 2 diabetes must await more research into the genetic subgroups associated with medication response (25).

THE DISCOVERY OF PRECISION MEDICINE

Precision Medicine is a developing subject, the core ideas have been present for well over a century and used by relevant organizations (26). In 1901, Karl Landsteiner identified blood classes, ushering in the era of greater awareness of individual

variation in blood composition and physiology. Therefore, the technical progress that is accessible now is essential for precision medicine to reach maximal predictive capacity (26). Innovative omics technologies, such as complete genome sequencing and multi-gene panel testing, have recently enabled the use of scientific techniques for precision medicine. This has kicked off a healthcare revolution that will be heavily reliant on the collection and analysis of data from fields like radiology, biology, and computer science.

PRECISION MEDICINE

Precision medicine was first introduced to the general public in an article published on April 16, 1999. Predictive safety and efficacy biomarkers (9) were examined, along with the ineffectiveness of present pharmacological therapies, illness heterogeneity, genetic variation, and a conflict with the "one size fits all" mindset. The United States' National Institutes of Health (NIH) define precision medicine as an emerging method for treating and preventing disease that takes into account individual variation in genetics, the surrounding environment, and one's own habits and behaviors (9). Patients are classified using large-scale data sets that include clinical, lifestyle, genetic, and other biomarker information, which is a step beyond the traditional "signs and symptoms" approach (21).

When it comes to healthcare, precision medicine encompasses not just medication but also diagnosis, prevention, and prognosis. The procedure of using genomic, medical, as well as scientific data to determine suitable treatment for different types of patients remains the same (27). For a more patient-centered strategy in encouraging successful therapies and minimizing unwanted effects, it makes use of various predictive indicators of response. The genetic, biochemical, phenotypic, and psychological

characteristics that distinguish one patient from another while having similar clinical symptoms provide the basis for individualized therapy (28).

Precision medicine employs methods such as molecular diagnostics, molecular imaging, next-generation sequencing, and molecular dynamics to identify illnesses and individualize therapies (28).

Individualism is at the heart of this method, which is medication based on a person's unique genetic makeup, behavioral tendencies, and contextual context (29). Modern advocates of precision medicine want to advance two areas: the ability to tackle and gather new data links indicating the incident and prevention of illness, and the field of pharmacogenetics, which is the development of medicines based on genetic data. By locating genes, biomarkers, or other factors that influence the risk of getting or treating illnesses, researchers hope to offer more tailored therapies (30). Precision medicine has replaced the average patient's illness management with individualized care that takes into account each person's unique characteristics (26).

Care delivery that is informed by data, analytics, and information is called "precision medicine" (31). This approach combines cutting-edge diagnostic and therapeutic tools to tailor healthcare to each individual patient, rather than standardizing preventative and therapeutic regimens. The overarching objective is to increase our understanding of the interplay between genetics and environmental factors in health and disease (32). This information might help clinicians better tailor medications for treatment or prevention to the needs of individual patients, as opposed to relying on the current strategy of symptom classification, which is limited by erroneous and unsuitable therapeutic options (33). Several criteria are used to evaluate a patient's condition, disease risk, prognosis, therapeutic response, and treatment need. There are several potential sources for data gathering for the multidimensional approach (34), including

but not limited to conventional medical records, smart devices, behavioural monitors or wearables, and genetic information.

Through tailored testing and medication, precision medicine aims to establish the best treatment plan for each patient. Precision medicine, in contrast to conventional medicine, employs analytics in order to cater a treatment plan to the unique requirements of each patient. When comparing personalized medicine to customized medicine, it is important to note that, the former takes into account just a patient's genetic composition and molecular traits, while the latter also takes into account elements like the patient's history, preferences, and socioeconomic level (35). Precision medicine, or treatment targeted to particular subgroups of patients with comparable characteristics, is just as important as personalized medicine when it comes to improving patient outcomes. "Precision medicine" (36), also known as tailoring diabetes treatment and prevention to an individual's own genetic composition, environmental conditions, and life circumstances, is becoming more popular.

An enhanced characterization of diabetes diagnosis that takes into account the individual's biology, environment, and context, as revealed by data from medical records or wearable technology, is an example of precision diagnosis within the broader field of precision medicine (35).

Predicting how a patient will react to medical procedures is what precision prevention is all about. Its broad applicability means it may be utilized for preventative measures across whole populations. Accurate diagnosis is used by medical professionals to select the most effective treatment with the fewest adverse effects. Predicting the likelihood and severity of diabetic complications using a patient-centered approach is the goal of precision medicine's prognostics component (37).

Accurate diagnoses are used to meet certain requirements. For instance, genetic testing can pinpoint a specific kind of monogenic diabetes, allowing for the development of highly effective and reasonably priced treatments. However, the wide variety of diabetes manifestations among populations makes diabetes categorization a challenging problem for precision medicine. Clinical research and ethnic representation also vary widely between communities, which may explain why people of different ethnicities experience diabetes in different ways. Due to the prevalence of data sets composed of people of a single ethnicity and area, it is possible that the results cannot be extrapolated to other groups. Data gathered in North America, for instance, may produce inaccurate results if applied in Asia. The use of very precise diagnostic tools is not warranted everywhere. Instead, they need to be adjusted for the unique characteristics of each group (37).

THE ROLE OF PRECISION MEDICINE

A. Methods for Avoiding and Preventing Disease

The widespread use of omics devices and the compilation of enormous volumes of medical, environmental, and behavioral information facilitates digital care and monitoring of patient health as well as disease care. Because of this, a standardized method of real-time management have to emerge, and novel opportunities for high-quality, individualized medical treatment might open up (26).

B. Customized Care

Precision medicine mixed with modern technology advances may more precisely focus disease therapy and management. Patients' genetic, biological, morphological, and pathological tissues can now be digitally recorded, observed by analytical instruments; big data can be evaluated with machine learning algorithms and artificial intelligence; data can be shared via file systems and distributed datasets; and big data can be digitalized.

C. Future of Healthcare Forecast

Many stages of a patient's life cycle have benefited from precision medicine applications, including preconception genetic screening to assess a woman's risk of passing on a genetic problem to her unborn child (38). In addition, non-invasive prenatal testing at the first trimester will be great for screening for peculiar developmental deformation in the fetus.

In addition, sequencing enables speedy postnatal identification of critical disorders, cutting down on morbidity and death. In the future, the same method could be used to detect health issues (38).

THE NEED OF PRECISION MEDICINE IN DIABETES

To evaluate the efficacy of precision medicine in the treatment of diabetes, the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD) launched the Precision Medicine in Diabetes Initiative (PMDI) in 2018.

When making clinical choices, clinicians used to rely mostly on information gleaned from a patient's physical exam, medical history, and standard laboratory testing. Large volumes of genomic data are used to define individual genetic variations, cellular activities, and environmental contexts in the service of precision medicine's goal of improved illness diagnosis and treatment. Potential results are highly dependent on a number of factors, including the patient's physiological and genetic characteristics (13).

Using precision medicine methods, doctors may provide patients individualized treatments with a better chance of success and fewer negative side effects. Studies (39) have demonstrated that compared to traditional clinical care, this method yields better clinical results and is more cost-effective.

Precision medicine is attempting to solve the problems of the O4 (Over testing, Over diagnosis, Overtreatment, and Overcharging) and P4 (Predictive, Preventative, Personalized, and Participatory) medical paradigms (40, 41). The potential for more individualized approaches to diabetes care increases as our knowledge of the disease's genetic, proteomic, and metabolomic aspects grows (10).

Many clinical guidelines in the area of diabetes treatment have moved away from a standard strategy and towards a more individualized and comprehensive approach due to the variety of causal and mediating variables and their virtually endless permutations. Proponents of individualized treatment have emerged with the use of data from healthcare records. Next-generation sequencing and gene arrays may help dissect the molecular underpinnings of type 2 diabetes medication that worked for certain subsets of patients. Despite significant advancements in the area, pharmacogenomics has ongoing hurdles when used in clinical settings (42).

In the treatment of diabetes mellitus, sulfonylureas have shown remarkable effectiveness. Sulfonylureas are now more likely to be prescribed to patients with genetic abnormalities in diabetes, thanks to the rise of precision medicine in the area of diabetology (31).

DIABETES MANAGEMENT USING PRECISION MEDICINE

Precision medicine for diabetes prevention requires researchers to examine the connections between genetics, lifestyle, and treatment. Indicators of disease progression and general health condition, or biomarkers, are used to personalize therapy for each patient (34). In contrast to this, the use of genetic markers for the identification of vulnerable persons in the case of the common and avoidable type 2 diabetes is a contentious subject.

Type 2 diabetes may be avoided with a combination of lifestyle changes (such as eating well and exercising regularly) and medical therapies (such as controlling one's weight). This method of diabetes management has been shown to reduce the risk of serious complications and death by improving metabolic control. Comprehensive sequencing testing offers the potential to identify the mutation in over 80% of people with monogenic diabetes, paving the door for individualized diabetes therapy (8, 43, 44).

The widespread availability of electronic health data and genetic information has the potential to improve diabetic precision medicine. Individuals with borderline diabetes and pregnant women at risk of acquiring diabetes have been shown to respond differently to lifestyle changes. A study conducted by scientists in the US and Japan (45) found no evidence to support the claim that genetic screening for those at risk of diabetes would encourage them to make lifestyle changes.

Experts believe that increasing the adoption of population management measures that enable those at high risk of having the condition get the medical care they need is the most effective strategy to reduce the spread of diabetes (42). People with inherited forms of the aforementioned ailment are increasingly being put through genetic testing for the purposes of diagnosis, categorization, and therapy. Several doctors have argued that, persons who exhibit unusual symptoms of type 1 or type 2 diabetes, or who exhibit characteristics that are consistent with transmissible diabetes subtypes (8), should undergo genetic testing.

Identifying the underlying mechanisms that give rise to this variability across diabetes subtypes will allow us to personalize care based on the patient's unique clinical and molecular profile. Glycated haemoglobin (HbA1c) testing is used to track average blood sugar levels over the course of a few months. Diagnosing and managing

diabetes often involves doing a hemoglobin A1c test (46). There are frequent and rare variants of the haemoglobin gene. Common and rare genetic variations may contribute to underdiagnosis of diabetes in groups predisposed to the condition. Precision medicine requires the combination of phenotypic and genotypic approaches in order to determine the best treatment strategy for a patient (47). Evaluation of the patient's individual features and the medicine being used is essential in diabetes treatment (48).

Several possible predictors of patients' responsiveness to glucose-lowering drugs have been found using the MASTERMIND approach, which was supported by MRC/APBI. Ethnicity, body mass index (BMI), sex, hemoglobin A1c (HbA1c), age, are all factors that may be used as predictors. Previous studies have shown that the quantitative impact of different therapies may explain their effectiveness and longevity (49). Before the development of biomarkers like indicators of insulin secretion or resistance, glycated hemoglobin level, and estimated glomerular filtration rate, basic personal parameters like body mass index and age were used to select oral anti-diabetic medicines (OADs) (49).

PRACTICES OF PRECISION MEDICINE IN DIABETES

Recently, the American Diabetes Association and the European Association for the Study of Diabetes released a study (34) highlighting the importance of precision medicine in diabetes as a focused treatment, particularly for the classification of specific gene abnormalities. Early diagnosis, successful treatment, and avoidance of environmental repercussions all depend on being able to distinguish autoimmune diabetes from other types of the illness. Previous studies have suggested subgrouping patients based on a mixture of illnesses and processes for optimal management and to build a personalized therapeutic treatment plan for type 2 diabetes (34).

Genomic clustering may be used in precision medicine to help find a cure for monogenic types of diabetes. To aid doctors in making educated clinical choices based on genetic information, we provide this MODY risk calculator. Approximately 4% of people who are diabetic have the condition because of a monogenic cause. However, studies of genetics have shown over 300 loci connected to Type 2 Diabetes (T2D).

Although genetics has the potential to improve our understanding of many illnesses, a thorough approach is still required to determine the optimal course of therapy for each person with type 1 or type 2 diabetes (9). Many international efforts have been launched to better understand the role precision medications play in treating type 2 diabetes, thanks to the explosive growth of big data, AI, and collaborative worldwide networks (50). Researchers found that different transmutations of the glucokinase (GCK) gene were associated with different illnesses in family members by linkage analysis (50). Compared to the general population, those who have GCK mutations are more likely to have higher plasma glucose thresholds that cause insulin production. The occurrence of moderate fasting hyperglycemia, as indicated by HbA1c values between 6-7%, is common among those who have this trait. Glycemic control methods, such as insulin or oral hypoglycemic medications, may not work as well for certain people. Thus, people with GCK mutations may not need to take blood glucose-lowering drugs, even if other common genetic variants and lifestyle-related variables hinder cellular function and increase the risk of long-term problems. Diabetes is strongly heritable, as around 60% of young Chinese people diagnosed before age 40 have autoimmune symptoms and unusual gene abnormalities (51).

BARRIERS OF PRECISION MEDICINE IN DIABETES

Large-scale randomized scientific trials, which are regarded the "gold standard," are impractical to execute in the light of medicine's fast expansion and innovation, making it difficult to acquire the necessary data. Data collection with the goal of developing new templates to address risk factors and encourage data interchange between healthcare institutions, technologists, and other stakeholders has been proposed in a novel way. The necessary information is anticipated to be provided by a growing number of large-scale diabetes research consortia, such as Go-T2D, T2D-GENES, and DIAGRAM, as well as future comparative potency research, including the Glycaemia Reduction Approaches in Diabetes (GRADE) (51). The use of insulin might be reduced, treatment effectiveness could be maximized, and prognosis and individualized healthcare could be facilitated by genetic identification and the administration of specialized medicinal therapies. Recent advances in epidemiology have opened up new opportunities for studying the role of pharmacogenetics in complicated hereditary forms of type 2 diabetes (52).

Additionally, there are racial and ethnic differences that contribute to regional and intra-regional differences in diabetes phenotypes and risk genes. Individuals of Native American heritage have a higher chance to get type 2 diabetes than those of European ancestry due to a genetic predisposition. Pharmacological results are anticipated to vary by community due to ethnically distinct differences in the diabetic phenotype (34). Careful assessment of both individual patient and drug features is required for effective diabetes treatment. Further challenges that precision diabetes treatment must overcome are described below.

A. Critical Facility Data and Infrastructure Interoperability

Scarcity of IT infrastructure, incompatible data formats, practical limited system, insufficient decision-making support systems, alongside lack of funding for recapitulation health studies are just some of the obstacles standing in the way of widespread adoption of precision medicine technologies in clinical settings (38). To facilitate the widespread use of precision medicine technology in healthcare delivery, it is proposed that, the creation of collaborative agendas and international standards be emphasized (38). Recent research (50) investigated the feasibility of using genetics for diabetes diagnosis, prevention, and therapy. The study used data from different illness phases to emphasize the difficulties of putting scientific discoveries into practice. Scholars agree that the lack of clinically meaningful findings is preventing the widespread use of genetics in diabetes care (50).

Similar to other forms of omics data, genomic data needs a framework for evaluating its reliability and value before practicing at the clinical level (53). Effective digital health information management, genetic data integration, and a modifiable clinical decision support system (53) are all possible using the approach suggested in this research.

B. Cost

Managing the increasing complexity of omics data and integrating cutting-edge supervised and unsupervised learning approaches requires an expensive High-Performance Computing (HPC) infrastructure. An important problem in precision medicine is the creation of an HPC algorithm that can efficiently analyze multidimensional datasets (33).

Because of technical and computational advancements, researchers all around the globe now have access to vast data banks including biological and clinical information (33). Implementing precision medicine in public health settings relies

heavily on accurate translation of data into actionable health information (54). Public health experts today face new challenges as a result of the rise of precision medicine, including the availability of a plethora of multi-omics, environmental, and behavioural data at the person level. This was determined by comparing traditional "public health" treatments directed at broad groups of people with "precision public health" interventions focused at the unique requirements of each individual patient (54).

C. Information Sharing and Protection Strategy

The promise of precision medicine will only be realized if patients and consumers work together to build a solid foundation. Although there are many upsides to implementing precision medicine, it does raise the issue of what counts as "informed consent" when it comes to patient participation and reassurance (38). It is unclear who should make choices about how genetic information should be used in research, and who should own the data in the first place. Can any safeguards be put in place to ensure privacy? In the medical community, which patient outcomes are prioritized the most? (38). Medical records fall under the category of confidential data because they need extra precautions to be taken at every stage of its lifecycle, from collection to storage to distribution. Accidental data breaches are very serious crimes (33).

VISION OF PRECISION MEDICINE IN DIABETES

Further investigations are necessary to establish a solid empirical foundation for the implementation of precision medicine, with an emphasis on elucidating its potential to either exacerbate or ameliorate existing disparities in healthcare access (38). The integration of data across various systems and platforms is deemed essential, alongside the extraction of data from pre-existing silos through data mining

techniques. To create a truly global healthcare system, one that can provide real-time data for both preventative and therapeutic interventions based on the specific needs of individual patients, it is necessary to incorporate clinical, behavioural, and environmental data pertaining to each patient's health status. In order to expedite the effective integration of precision medicine in the management of diabetes, it is imperative to develop training models that are reliable, replicable, and dependable (38). Equipping physicians with instructional resources that facilitate the appropriate utilization of intricate and sophisticated data types is a crucial component of implementing precision medicine in the management of diabetes. The increasing accessibility of genetic and digital health data among individuals may potentially yield significant implications for genomic discovery, as indicated by recent research (8).

Healthcare professionals will need to undergo training on the benefits and drawbacks of precision medicine to effectively utilize data produced by artificial intelligence for clinical decision-making purposes. To effectively manage multidimensional omics data, businesses will require access to advanced high-performance computing infrastructure, which is augmented by state-of-the-art artificial intelligence technology (33). It is imperative for clinicians to remain receptive to the expanding domain of technology-based biological phenotypic levels to establish causal links between various illnesses, therapeutic responses, and clinical outcomes. The escalating prevalence of diabetes across all demographics, particularly in emerging economies owing to differences in the incidence of various forms of diabetes, underscores the need for leveraging technology to educate, cultivate, and re-educate individuals with the requisite knowledge in biology and data science to propel precision medicine in diabetes interventions. Additionally, it is imperative to engage patients, the end-users,

in the development of novel clinical pathways that can ultimately enhance their well-being. It is imperative to establish a standardized protocol (34) across all relevant organizations for the validation and dissemination of precise diagnostic tools and therapeutic agents. It is recommended that health professionals and their respective regulatory bodies collaborate to establish ethical standards and protective measures for aggregated "precise" data. This is to prevent any potential misuse, data breaches, and privacy concerns that may arise for various populations and nations.

The significance of social and environmental factors are frequently overlooked by researchers when analyzing the factors that influence the suitability of therapy for a particular population. The classification process tends to overlook the social and environmental factors that exert a substantial impact on individuals' health, thereby limiting the scope to only biological and behavioral aspects (55). To date, there has been a lack of inquiry into the potential correlations between an individual's lifestyle and their overall well-being (55). Globally, there has been a surge in the incidence of diabetes mellitus, with a significant increase in the number of diagnosed cases (55). Recent genetic discoveries have enabled the development of precision medicine for the customized management and treatment of diabetes (55). The possible avenues for future exploration in this study are both captivating and formidable. It is likely that a comprehensive understanding of the various types of diabetes will require a multifaceted approach involving specialized investigation of human islets, advanced analytical techniques applied to a large demographic cohort, state-of-the-art molecular genetic methodologies, rigorous research protocols, and other innovative tools. The establishment of a solid foundation for the identification and management of diabetes in its various manifestations is expected to yield enhanced clinical outcomes.

CONCLUSION

The increasing computational power of AI in machine learning and cloud computing techniques to data sharing (26), necessitates consistency in data collecting and processing. The remark has great significance in the context of omics technology and digital sensing devices.

Future opportunities to use scientific findings are anticipated to improve via the establishment of a worldwide clinical research network that places a premium on increasing public awareness of and openness to the potential benefits of precision medicine in diabetes treatment. The best treatment and care for people with type 1 and type 2 diabetes should be the focus of future research. Data collected and care delivery (online vs. in-person, one-on-one and/or group interaction) determine the scope of research questions that must be addressed before diabetes may be avoided precisely (34).

Medical professionals treating diabetes with precision medicine must consider several things outside the patient's health and finances to provide therapy that is tailored to the person's unique set of circumstances. In a future world when diabetes is the most common disease, only the wealthy will be able to afford the deployment of individualized therapy based on genetic categorization. Patients with diabetes should have the freedom to choose their own treatment plan based on objective metrics like body mass index (BMI), estimated glomerular filtration rate (eGFR), and age (27), which would help bring precision medicine to a wider population.

For precision medicine to advance, widespread access to patient data is essential. Healthcare research that makes use of genomics is only as good as the data with which it can be worked. Therefore, it is crucial to make a concerted effort to improve system interoperability, so that better data mining may be done for the benefit of

patients in general and during treatment in particular. Integrating information from many sources on a patient's genetic make-up, environmental context, and other pertinent elements is essential for the creation of a holistic precision medicine framework.

The sharing of information and clinical systems has the potential to improve healthcare delivery throughout the world by raising awareness and sensitivity. Achieving success in clinical practice and scientific developments is essential for improving the detection, diagnosis, and treatment of illness. If precision medicine can be made more inexpensive, it will be able to help a wider range of people. Although precision medicine has been used to investigate diabetes, the societal cost is often disregarded. It has been shown that poor and middle-income nations have a higher prevalence of diabetes than high-income countries. In addition, a large percentage (81% to be exact) of the world's 537 million diabetics live in these nations (56). For proper diabetes treatment and diagnosis, it is crucial that these people have access to precision medicine (56). The Sustainable Development Goal (SDG) 3 indicates the provision of healthy lifestyles and the promotion of well-being across all age groups; this measure would help to the realization of this goal. Precision treatment relies on being available to people with diabetes if it is to be effective in the management of the disease. It is crucial that academics devote more time and energy to studying the ways in which patients' social and environmental contexts influence their health in order to improve the precision with which diagnoses and treatments are administered.

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