Nanotechnology in Diabetes Mellitus: Overview for Nurses

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Abstract

Nursing takes pride in being by the client's area in the period of need, whether in the hospital or in the community. The social agreement is based on a connection for providing holistic care during the care continuum. Therefore, health care professionals must educate and prepare themselves to adapt to the latest diagnosis and drug delivery system technology. Nanotechnology is one of the leading technologies which provide sensing technology and miniature devices to accurately and quickly diagnose disease. Nanotechnology is a multidisciplinary research discipline that uses biology, chemistry, and engineering to improve the quality of life through disease prevention, diagnosis, and treatment at an early stage. This article aims to keep nurses up-to-date on nanotechnology in diabetes mellitus (DM) and how to use it in their practice to improve the quality of nursing care.

Keywords: Diabetes mellitus, Nanotechnology, Nurses.

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Introduction

Diabetes mellitus (DM) is a metabolic disease characterized by increased blood glucose levels (BGLs). Diabetes affects approximately 537 million adults aged 20–79, according to the International Diabetes Federation 2021. The total cases of diabetics are predicted to rise to 643 million by 2030 and 783 million by 2045. Diabetes is undiagnosed in nearly 240 million adults and responsible for 6.7 million deaths.[1]

Diabetes is classified into type I, type II, and gestational. Type 1 diabetes mellitus (T1DM) can arise at any age, but it is most general in children and adolescents. Because the body produces less or no insulin in this condition, everyday administration of insulin injections is essential to keep BGLs in control. Adults are further likely to develop type 2 diabetes mellitus (T2DM), accounting for roughly 90% of all diabetes cases. In T2DM, the body does not make good use of the insulin it produces from the beta-cells of the pancreas. Gestational diabetes mellitus (GDM) is a condition that results in increased BGLs during pregnancy and is related to complications for the mother and the baby. Gestational diabetes mellitus (GDM) typically resolves after delivery, but mothers with it and their children are more likely to develop T2DM in their later years.[2]

The significant possible factors are a positive family history of diabetes, being over 35-years-old, being overweight (BMI $\geq$33 kg/m^3), increased waist circumference or upper body adiposity (>90 cm for males and >80 cm for females), increased blood pressure, increased body weight, sedentary lifestyles, and GDM. Diabetic symptoms include polyuria, polydipsia, severe weight loss, and polyphagia.[3]

Based on the American Diabetes Association, diabetes can be diagnosed using one of the criteria listed below: glycosylated hemoglobin (HbA1c) $\geq$6.5%, fasting plasma glucose $\geq$126 mg/dL, and random plasma glucose $\geq$200 mg/dL. The primary approach for DM is to control and monitor the BGL with the administration of insulin injections to keep them within the normal glycemic range of 70–140 mg/dL.[4]

Diabetes mellitus (DM) treatment includes insulin administration for T1DM. Type 2 diabetes mellitus (T2DM) comprises oral medications and daily life changes, such as weight loss, preparing nutritious foods, and increasing physical activity. In addition, dietary changes and regular exercise may treat GDM.[5] Diabetic complications include retinopathy, nephropathy, neuropathy, heart attacks, coma, and lack of blood flow to a leg.[6]

The term "nano" comes from the Greek word for "dwarf." Richard Feynman developed the concept of nanotechnology in 1959. In 1974, a student at a Tokyo Science University coined the term "nanotechnology." Nanotechnology refers to the ability to quantify, design, and influence materials at the atomic molecular and supramolecular levels in order to understand, produce, and implement structures and systems with precise functions attributable to their size.[7]

The impact of nanotechnology on the medical field can be seen primarily in investigations, drug administration, and regenerative medicine. In medical diagnostics, microbiology and nanobiotechnology are applied in two ways: *in vitro* diagnostic devices [nanobiosensors, microarrays, biochips of various elements (DNA, proteins, or cells), and lab-on-a-chip (LOC) devices] and *in vivo* imaging [luminescence microscopy, scanning probe microscopy (SPM), electron microscopy (EM), and imaging mass spectrometry].

In Vitro Diagnostic Devices

A biosensor is a sensing gadget or measurement system that quantifies a substance using genetic connections and then assesses these connections into a legible form using transduction and electromechanical interpretation. These components, in aspects of the abstract and elemental way of operating, are bioreceptors, sensors, and analyzers. The primary function or purpose of a biosensor is to identify biologically particular materials. Immunoglobulins, peptides, enzymes, and immune particles are frequently used as these materials.

A microarray is a laboratory tool that detects the expression of thousands of genes at once. DNA microarrays are microscope slides with thousands of tiny spots in specific positions, each containing a known DNA sequence or gene. A biochip is a group of miniaturized test sites (microarrays) organized on a solid substrate that enables several tests to be accomplished simultaneously for increased throughput and speed. There are three types of biochips: DNA microarrays, protein microarrays, and microfluidic chips. A LOC is an apparatus that consolidates one or more laboratory functions on a single integrated circuit ("chip") ranging in size from millimeters to a few square centimeters to attain mechanization and high-throughput screening.

In Vivo Imaging

The sensing of light reflected by human tissue conveying a luciferase genotype or another luminescence-related genotype is the foundation of bioluminescence microscopy. Scanning probe microscopy (SPM) is a type of microscopy that creates images of surfaces by scanning the specimen with a physical probe. The technique of EM produces high-resolution images of biological and nonbiological specimens. Mass spectrometry imaging is a technique that uses molecular masses to visualize the spatial patterns of biological molecules, such as proteins, peptides, fatty acids, and other organic molecules.[8]

Nanotechnology in the Diagnosis of Diabetes Mellitus

Biosensor

The concept of a biosensor for measuring glucose levels was first proposed by Clark and Lyons in 1962. Continuous glucose monitoring (CGM), a noninvasive or minimally invasive physiological monitoring device, has recently been victorious in detecting glucose levels in sweat, saliva, urine, tears, and interstitial fluid that may be related to BGLs.[9] There are several CGM biosensor devices on the market, including 1. FreeStyle Libre Pro and FreeStyle Libre to identify glucose levels in interstitial fluid; 2. The Dexcom G4 Platinum (Pediatric) device is indicated for detecting diabetes in children (ages 2–17 years). The Dexcom G6 is a sensor worn on the abdomen that transmits data to a corresponding app that can be downloaded on a phone, tablet, or smartwatch;[10] 3. Jiang et al. reported the development of a breathing acetone analyzer capable of detecting acetone levels in diabetic clients; 4. Human sweat analysis is performed using wearable/disposable sweat-based glucose sensors; 5. Zhang et al. created a nonreusable microfluidic gadget that was designed as a diagnostic instrument for quantifying saliva glucose concentrations using electrochemical methods; 6. The Google [X] Lab collaborated on the development of glucose-sensing technologies in aqueous humor; 7. The smart tattoo is made up of an intradermally surrounded array of biosensors that are exposed to interstitial fluid and can detect local changes in glucose that corresponds to BGLs;[11] and 8. Smart underwear for diabetic patients is available in both men's and women's styles, with the ability to measure various physiological data using glucose-sensing bioimplants and biosensors. Sensors, data processing, a central monitoring system, storage, and communication are among the features of this smart underwear.[12]

Nanotechnology in the Management of Diabetes Mellitus

Oral Delivery

Oral insulin administration will be the most convenient method of treating DM because it tries to avoid the inconvenience of invasive and painful subcutaneous injections. When insulin is administered orally, gastric enzymes constitute a significant barrier because that humiliate insulin in the gastrointestinal tract. As a result, it is expected to be encased in a structure to protect itself from the tough conditions of the stomach. According to Cui et al., entrapping insulin in the shell of the carboxyl group's chitosan-implanted (methyl methacrylate) nanoparticles enhanced insulin delivery efficiency.[13]

Smart Insulin Pens

Inpen™ is a registered trademark for electronic, linked insulin pens that instantly transfer information about the time and quantity of insulin prescribed to the user's smartphone, trying to remind the user about the insulin dose and assist in the calculation of the dosage. Using Bluetooth® technology, hospital information from the smart insulin pen is wirelessly transferred to a smartphone application. As a result, smart insulin pens require an app to collect data from the pen but eliminate the need for a manual self-report record book.[14]

Insulin Pump

A small, portable electronic pump that infuses medication at a slow basal rate and is thought to be ideal for titrating insulin doses in children and adolescents to avoid low blood sugar. Several insulin pumps now have built-in features, such as blood glucose monitoring and CGM systems, for injecting insulin in T1DM patients. The Medtronic MiniMed 630G system, Medtronic MiniMed 770G system, Omnipod DASH, and t:slim X2.15 are examples of insulin pumps on the market.[15]

Inhalation Insulin Powder

The new nanotechnology-based insulin system inhales insulin rather than injecting it, enabling for slow release into the blood. In comparison to the gastrointestinal route, inhaler systems provide a more conducive atmosphere, such as low catalyst densities and balanced pH. Active products can be delivered using a variety of inhaler systems. Among the most common are dry powder formulations and solutions. Because the nanoparticles comprise insulin, the dehydrated particle preparation could be absorbed into the lungs. As a result, insulin degradation is avoided, ensuring that insulin reaches the bloodstream. To maximize efficacy, patients must undergo regular lung function tests before treatment, which increases the likelihood of success.

Nano-pancreas

Developing a synthetic pancreas structure that incorporates an uninterrupted glucose monitor, a glucose meter, and an insulin infusion pump for screen calibration could provide a long-term solution for patients with DM. The original concept was first demonstrated in 1974. The basic idea behind this concept is a sensor electrode that can repeatedly measure the level of blood glucose, with the data being fed into a tiny computer. This process can activate an infusion pump, and insulin units from a small reservoir can enter the bloodstream. An alternative approach is to use a tiny silicon box containing animal-derived pancreatic beta-cells. This application shields transplanted cells from the immune system. It also allows for adequate glucose, insulin, and oxygen diffusion. Diabetes patients can have it implanted under their skin. This container is encased in a substance with a predetermined nanopore size. These pores permit glucose and insulin to proceed across by preventing much larger immune system molecules from passing through.

Developing a smart insulin patch is a potential step forward in insulin delivery. This device is referred to as "smart" because it can discharge insulin to the needs of the body. It includes a bunch of over hundreds of microneedles that are preloaded with insulin and glucose-sensing enzymes. The recent scientific endeavor includes the progress of a nanorobot with surface glucose level sensors and insulin departed in inside chambers. The surface sensors detect any rise in BGLs, triggering selective insulin release.[16]

Nursing Implications of Nanotechnology in Diabetes Mellitus

A constant technological revolution has been introduced to treat DM. Clients, doctors, public health organizations, health care systems, consumers, and people all require advocates for nanotechnology's safe and ethical applications. Institutions must be cautious when deploying nanotechnology applications because of various concerns related to responsibility, privacy, finance, and product safety and efficacy. Among the health care team, nurses have much closer contact with the patients and enable them to effectively communicate about the new devices, ensuring that they are well-informed and can make sound treatment decisions. As nursing advances through technological transformation, nurse leaders will be challenged to establish a framework of care that protects values while providing patients with dignity and respect. As a result, nurses must educate and prepare themselves to adapt to the most recent technology in the monitoring of glucose levels and administration of insulin in DM and also be aware of workplace safety.[17]

Role of Nurse in the Application of Nanotechnology in Diabetes Mellitus

Nurses play a significant role in educating clients about disease prevention, promotion, and rehabilitation. Diabetes necessitates the encouragement of self-care activities. As a result, at-home glucose monitoring and insulin administration can help reduce the major complications of DM. Hence, nurses play an important role in teaching and demonstrating to patients how to use and apply new technological devices.[18]

Conclusions

The impact of nanotechnology on medicine cannot be overstated. Nanotechnology-based techniques assist in developing new diabetes treatment strategies, such as glucose-responsive insulin therapy. Diabetes patients will benefit significantly from uninterrupted glucose monitoring devices and insulin delivery systems, such as nano-pancreas. Nanotechnology promised to eliminate the time lag between glucose detection and insulin delivery, thereby ignoring potentially unsafe situations, such as low blood sugar. In conjunction with advanced nanodevices, the next generation of nanocomposite-mediated insulin is expected to improve diabetic patients' daily lives in the future. In addition, nanotechnology has been shown to be beneficial in treating DM.

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