Scholars LITERATURE

Obesity and Diabetes Research

Short Commentary

DOI: https://doi.org/10.47275/2692-0964-106
Volume 1 Issue 2

Managing Diabetes with Nanomedicine

Perihan Gurbuz*

Vocational School of Health Services, Inonu University, Malatya, Turkey

Abstract

Diabetes Mellitus, as a widespread chronic disease, gives rise to serious acute and chronic complications. The disease, not only affects the life quality of the patients negatively but also causes high costs for health and work systems. There exist serious insufficiencies in diabetes diagnosis and treatment modalities. In this aspect, new researches about prevention, diagnosis, and treatment of diabetes are done in a widespread manner. Among these researches, nanotechnology-based studies about diabetes gain attention. Nanotechnology studies in diabetes management focus on diagnostic methods, glucose monitoring, insulin, and drug delivery, and islet implantation. In this review, a general view about the pointed out topics have been mentioned.

Keywords: Diabetes; Research; Nanotechnology

Correspondence to: Perihan Gurbuz, Vocational School of Health Services, Inonu University, Malatya, Turkey; E-mail: perihan.gurbuz@inonu.edu.tr

Citation: Gurbuz P (2020) Managing Diabetes with Nanomedicine. Obes Diabetes Res, Volume 1:2. 106. DOI: https://doi.org/10.47275/2692-0964-106.

Received: July 01, 2020; **Accepted:** July 15, 2020; **Published:** July 25, 2020

Introduction

By the four-fold increase in the patient number after 1980, Diabetes Mellitus (DM) is defined as the epidemics of the twenty-first century [1,2]. While DM prevalence is estimated to be 8.5% in adults, World Health Organisation (WHO) warns about the high percentage of undiagnosed diabetes patients and increasing rates of diabetes-induced premature mortality among the other non-communicable diseases [1]. Besides, the rising prevalence of DM has been reported to be more rapid in low or middle-income countries, where health service may not be adequate. DM, not only with direct treatment costs but also with a disease caused by complications and loss of work time costs, is considered as an expensive disease for economics [3]. Therefore; preventive, diagnostic, and curative policies about DM gain importance for the health systems.

DM is defined with a high blood glucose level. There exist many subtypes of DM, but the common forms are Type 1 DM (T1DM), Type 2 DM (T2DM), and gestational diabetes [4, 5]. T1DM is characterized by insufficiency and/or lack of insulin as the result of β-cell damage in the Langerhans islets of the pancreas and constitutes about 10% of all DM patients [5,6]. As an autoimmune disease (70-90% of patients have autoantibodies) T1DM is related among different aspects as; genetics, epidemiology, immune system, and β-cell phenotypes [7,8]. T2DM is characterized by decreased insulin sensitivity and/or increased insulin resistance in tissues and constitutes 90% of all diabetic cases [9]. The main factors of the increasing prevalence of T2DM are admitted as; rising obesity ratios, sedentary lifestyle, energy-dense diets, and population aging [9].

Regardless of the type, the main goal in DM treatment is the blood glucose level regulation. Fasting blood glucose levels in the range of 3.5–5.5 mmol/L (75-110 mg/dL) is accepted normal [10]. Inadequate serum glucose concentration control and DM treatment give rise to acute and chronic complications. Acute complications are diabetic ketoacidosis, hyperosmolar hyperglycaemic syndrome (HHS), and hypoglycaemia, which have short-term mortality risks [11,12]. According to American Diabetes Association (ADA), serum glucose levels >13.9 mmol/L (250 mg/dL) and >33.3 mmol/L are considered as ketoacidosis and hyperosmolar hyperglycaemic state respectively [12]. Both ketoacidosis and HHS result from insulin deficiency and they present with severe hypovolemia, arrhythmias, and altered mental status [11,12]. Besides idiopathic cases, hypoglycaemia commonly emerges as an adverse effect of DM treatment in 10-40% of all DM patients, and decrease health-related life quality and work productivity, besides increasing risk of falls and absenteeism [11]. Chronic complications of DM are mainly categorized as micro vascular and macro vascular complications, which in time frequently cause serious; ophthalmic (retinopathy), renal (nephropathy), neuronal (neuropathy) and vascular (coronary heart disease, cerebrovascular disease, peripheral vascular diseases) morbidities [13].

As mentioned before, the main goal to prevent diabetic complications is to maintain normoglycaemic status. While insulin replacement is the basic treatment modality in T1DM, different treatment protocols including biguanides, sulfonylureas, meglitinides, dipeptidyl peptidase (DPP)-4 inhibitors, thiazolidinediones, sodium-glucose cotransporter (SGLT)-2 inhibitors, α-glucosidase inhibitors, glucagon-like peptide (GLP)-1 receptor agonists and also insulin replacement (when necessary) are widely used in T2DM treatment to decrease insulin resistance and/or increase insulin sensitivity [14,15]. However, the expected success in DM treatment has not been fully achieved until the day [14]. One of the factors affecting the DM treatment success is the gastrointestinal enzymatic environment based negativities and the related need for chronic subcutaneous injection of insulin and some other antidiabetics [16]. Because of these reasons, for both diabetes treatment and complication management, new therapeutic alternatives that will be accepted and easily used by the patients are in search [17-19]. Among different approaches, nanotechnology-based modalities take an important place in DM prevention and treatment.

Nanotechnology usage in medicine is a new concept of the twenty-first century, Nano science studies on substances of a 1-100 nanometer (nm) scale. Regarding the dealing sizes (a DNA double helix has a radius of 1 nm and thickness of a single human hair is 60,000 nm), nanotechnology emerges as a promising science for nearly all aspects of life including electronics, engineering medicine, and medicine [20]. In medicine, nanostructures and devices are used for; analytics and imaging, theranostic, targeted therapy and drug delivery, and tissue engineering regenerative medicine. These application areas provide improved prevention, diagnosis, and treatment facilities for many diseases including diabetes [21,22].

When nanotechnology-based researches and DM are evaluated, the studies focus mainly on diagnostic methods, glucose monitoring, insulin and drug delivery, and islet implantation [23-25].

Diagnosis

The β-cell residue is an important factor in the diagnosis and prognosis of T1DM. Besides, the determination of some pancreatic factors as islet amyloid polypeptide and a glucagon-like peptide-1 receptor is effective in DM diagnosis [26,27]. By this aspect, several nanomaterials have been determined to provide the strength of imaging methods as magnetic resonance imaging and positron emission computed tomography [7].

Glucose Monitoring

Carbon, gold, platinum, silver, quantum, and graphene quantum dots and/or nanoparticles are widely used materials in glucose monitoring [28,29]. Hydrogen peroxide sensitivity is the commonly used method in most of the systems [25,28]. Glucose monitoring nanotechnologies are broadly based on optical (nanotube near-IR emission, nanotube fluorescence enhancement, fluorescence enhancement, and AuNP growth, graphene catalytic activity, Raman spectroscopy, hydrogel mediated Bragg diffraction, protein FRET signal) and electrical categories (nanotube conductance modulation, hydrogen peroxide catalysis via nanotubes, hydrogen peroxide catalysis via AuNPs, nanomaterial enhanced conductance modulation, enzyme-free glucose catalysis) [25].

Insulin Delivery

The insulin hormone is a 51 amino acid protein, which is synthesized in β cells of pancreatic Langerhans islets in response to high blood glucose concentration. As mentioned above, it is the main hormone of glucose metabolism, and the main treatment modality of T1DM is insulin replacement [30]. However, as only 0.5% of oral administered insulin enter the systemic circulation, it has to be given by invasive routes, and this situation causes inadequacies in the treatment follow-up and patient compliance [21]. In recent years, advanced nanotechnology therapeutic methods in insulin delivery are in search [21,25]. These studies are based on; natural polymers (chitosan-insulin nanoparticles, alginate, biotin, sodium glycocholate, dextran-insulin nanoparticles), synthetic polymers (Poly (Lactic-co-Glycolic Acid) (PLGA), Polylactide, Poly-ε Caprolactone (PCL), N-vinyl pyrrolidone), polyalkylcyanoacrylate-insulin nanoparticles (isopropyl myristate + labrasol + plurol oleique + butyl (2) cyanoacrylate), solid lipid-insulin nanoparticles (lecithin + stearic acid + ploxamer + wheat germ agglutinin-N-glutamylphosphatidyl- ethanolamine, Witepsol 85E) and targeted insulin nanoparticles (N-trimethyl chitosan chloride + CSKSSDYQC peptide) [21,24,31-33].

Normally, insulin therapy is done with an open-loop system in which continuous blood glucose level determination has to be made, and insulin dosage has to be regulated [34]. Nanotechnological researches on DM treatment also focus on forming glucose-responsive closed-loop systems that work by hypoxia and hydrogen peroxide mediation [21]. Different researches on closed-loop systems can be summarised as; microencapsulation of islet cells (artificial pancreas), glucose-responsive insulin delivery, glucose binding protein (GBP) systems, glucose oxidase (GOx) systems, and phenylboronic acid (PBA) systems [25].

Drug Delivery

Nanomedicine based technologies are also in search of different types of antidiabetic drugs. Some of them can be listed as; liposome-based system (glycerolphosphate– chitosan microcomplexation for metformin, anionic liposomes containing DSPEPG8G, DPPC, cholesterol, and DPPG for GLP-1), niosome-based system (cholesterol, span 40, dicetyl phosphate for metformin, span 40/cholesterol dicetyl phosphate and DOTAP for metformin hydrochloride, span 60, cholesterol for repaglinide, cholesterol and span 20 for pioglitazone, span 60, cholesterol for gliclazide), and polymeric nanoparticle-based system (for repaglinide) [24,35-37].

Islet Implantation

Although islet implantation is an important and promising treatment modality in diabetes, desired success cannot be obtained because of the human donor organ shortage and immunosuppression side effects [38]. At this point, encapsulating cells with nanomaterials draw attention. Microencapsulation of islets by hydrogelation of alginate, Nano films structured by layer-by-layer (LbL) polymer self-assembly, and antigen nanoparticle in islet transplantation is widely searched nano techniques in islet implantation [7].

Conclusion

Diabetes Mellitus is a widespread chronic disease that causes serious problems for the patient and the health system. Therefore; prevention, diagnosis, and treatment are important factors in DM management. By this point, nanotechnology-based studies about the mentioned topics gain attendance. In this review, the researches about DM and nanotechnology have been summarised. However, there are still unsolved points in DM management, and multidisciplinary studies about diabetes and nanotechnology will be important in determining new approaches.

References

1. World Health Organization (2020) Diabetes. World Health Organization, Switzerland.
2. Schmidt AM (2018) Highlighting diabetes mellitus: The epidemic continues. Arterioscl Thromb Vasc Biol 38: e1-e8.
3. Leśniowska J, Schubert A, Wojna M, Skrzekowska-Baran I, Fedyna M (2014) Costs of diabetes and its complications in Poland. Euro J Health Econom 15: 653-660.
4. Association AD (2018) 2.Classification and diagnosis of diabetes: standards of medical care in diabetes-2018. Diabet Care 48: S13-S27.
5. ADA (2020) ADA Statistics about Diabetics. American Diabetes Association: Arlington.
6. Mao R, Chen Y, Chi Z, Wang Y (2019) Insulin and its single-chain analogue. Appl Microbiol Biotechnol 103: 8737-8751.

7. Pan W, Zheng X, Chen G, Su L, Luo S, et al. (2020) Nanotechnology's application in Type 1 diabetes. Wiley Interdisciplinary Reviews: Nanomed Nanobiotechnol 2020: e1645.
8. DiMeglio LA, Evans-Molina C, Oram RA (2018) Type 1 diabetes. The Lancet 391: 2449-2462.
9. Zheng Y, Ley SH, Hu FB (2018) Global aetiology and epidemiology of type 2 diabetes mellitus and its complications. Nat Rev Endocrinol 14: 88-98.
10. Güemes M, Rahman SA, Hussain K (2016) What is a normal blood glucose? Arch Dis Childhood 101: 569-574.
11. Umpierrez G, Korytkowski M (2016) Diabetic emergencies-ketoacidosis, hyperglycaemic hyperosmolar state and hypoglycaemia. Nat Rev Endocrinol 12: 222.
12. French EK, Donihi AC, Korytkowski MT (2019) Diabetic ketoacidosis and hyperosmolar hyperglycemic syndrome: review of acute decompensated diabetes in adult patients. BMJ 29: 365.
13. Gregg EW, Sattar N, Ali MK (2016) The changing face of diabetes complications. Diabet Endocrinol 4: 537-547.
14. Khursheed R, Singh SK, Wadhwa S, Kapoor B, Gulati M, et al. (2019) Treatment strategies against diabetes: Success so far and challenges ahead. Euro J Pharmacol 862: 72625.
15. Bailey CJ, Day C (2018) Treatment of type 2 diabetes: future approaches. Bri Med Bulletin 126: 123-137.
16. Pearson S, Kietsiriroje N, Ajjan RA (2019) Oral Semaglutide in the management of Type 2 Diabetes: A report on the evidence to date. Diabetes Metab Syndr Obes 12: 2515-2529.
17. Souto EB, Souto SB, Campos JR, Severino P, Pashirova TN, et al. (2019) Nanoparticle delivery systems in the treatment of diabetes complications. Molecules 24: 4209.
18. Lovaglio AC, Socolovsky M, Di Masi G, Bonilla G (2019) Treatment of neuropathic pain after peripheral nerve and brachial plexus traumatic injury. Neurology India 67: 32.
19. Gürbüz P, Düzova H, Yildiz A, Çakan P, Kaya GB, et al. (2019) Effects of noopept on cognitive functions and pubertal process in rats with diabetes. Life Sci 233: 116698.
20. Bayda S, Adeel M, Tuccinardi T, Cordani M, Rizzolio F (2020) The history of nanoscience and nanotechnology: From chemical–physical applications to nanomedicine. Molecul 25: 112.
21. Bahman F, Greish K, Taurin S (2019) Nanotechnology in insulin delivery for management of diabetes. Pharmaceut Nanotechnol 7: 113-128.
22. Patra JK, Das G, Fraceto LF, Campos EV, del Pilar Rodriguez-Torres M, et al. (2018) Nano based drug delivery systems: recent developments and future prospects. J Nanobiotechnol 16: 71.
23. Ali MK, Siegel KR, Chandrasekar E, Tandon N, Montoya PA, et al. (2017) Diabetes: An update on the pandemic and potential solutions. Disea Control Prior 5.
24. Kesharwani P, Gorain B, Low SY, Tan SA, Ling EC, et al. (2018) Nanotechnology based approaches for anti-diabetic drugs delivery. Diabetes Res Clin Pract 136: 52-77.
25. DiSanto RM, Subramanian V, Gu Z (2015) Recent advances in nanotechnology for diabetes treatment. Wiley Interdisciplinary Reviews: Nanomed Nanobiotechnol 7: 548-564.
26. Joosten L, Brom M, Peeters H, Heskamp S, Béhé M, et al. (2018) Enhanced specific activity by multichelation of Exendin-3 leads to improved image quality and in vivo beta cell imaging. Mol Pharmaceut 15: 486-494.
27. Godin E, Nguyen PT, Zottig X, Bourgault S (2019) Identification of a hinge residue controlling islet amyloid polypeptide self-assembly and cytotoxicity. J Biol Chem 294: 8452-8463.
28. Mello GP, Simões EF, Crista DM, Leitão JM, Pinto da Silva L, et al. (2019) Glucose sensing by fluorescent nanomaterials. Crit Rev Anal Chem 49: 542-552.
29. Santschi C, Von Moos N, Koman VB, Slaveykova VI, Bowen P, et al. (2017) Non-invasive continuous monitoring of pro-oxidant effects of engineered nanoparticles on aquatic microorganisms. J Nanobiotechnol 15: 19.
30. Jensen KJ, Østergaard M, Kumar NM (2020) The ABC of insulin: The organic chemistry of a small protein. Chem Euro J.
31. Zhang Z, Li H, Xu G, Yao P (2018) Liver-targeted delivery of insulin-loaded nanoparticles via enterohepatic circulation of bile acids. Drug Del 25: 1224-1233.
32. Picone P, Ditta LA, Sabatino MA, Militello V, San Biagio PL, et al. (2016) Ionizing radiation-engineered nanogels as insulin nanocarriers for the development of a new strategy for the treatment of Alzheimer's disease. Biomaterials 80: 179-194.
33. Sampathkumar K, Riyajan S, Tan CK, Demokritou P, Chudapongse N, et al. (2019) Small-intestine-specific delivery of antidiabetic extracts from Withania coagulans using polysaccharide-based enteric-coated nanoparticles. ACS Omega 4: 12049-12057.
34. Allen N, Gupta A (2019) Current diabetes technology: striving for the artificial pancreas. Diagnostics 9: 31.
35. Sciacca MF, Lolicato F, Di Mauro G, Milardi D, D'Urso L, et al. (2016) The role of cholesterol in driving IAPP-membrane interactions. Biophys J 111: 140-151.
36. Maestrelli F, Mura P, González-Rodríguez ML, Cózar-Bernal MJ, Rabasco AM, et al. (2017) Calcium alginate microspheres containing metformin hydrochloride niosomes and chitosomes aimed for oral therapy of type 2 diabetes mellitus. Int J Pharmaceu 530: 430-439.
37. Ebrahimi HA, Javadzadeh Y, Hamidi M, Jalali MB (2015) Repaglinide-loaded solid lipid nanoparticles: effect of using different surfactants/stabilizers on physicochemical properties of nanoparticles. DARU J Pharmaceu Sci 23: 46.
38. Dinnyes A, Schnur A, Muenthaisong S, Bartenstein P, Burcez CT, et al. (2020) Integration of nano-and biotechnology for beta-cell and islet transplantation in type-1 diabetes treatment. Cell Proliferat 53: e12785.