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Original Article

Potential Uses of Nanotechnology in Healthcare: Nanotechnology's Unique Properties as a Diagnostic Tool and Medical Domain

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Abstract:

Nanomedicine exists as one main healthcare field which benefits from nanotechnology applications. Various nanotechnology-based diagnostic and imaging tools together with pharmaceutical products alongside biomedical implants and targeted medicinal treatments and tissue engineering applications and several nanoparticles serve these healthcare fields. Nanotechnology enables high toxicity therapeutic cancer drugs and other treatments to receive improved safety profiles during administration. Wearable technology has the ability to detect critical indicator changes and cancer cell states and infections during real-time monitoring. These technologies situated in the fundamental problem will make essential data about vital sign changes and sickness causes readily accessible to doctors. Bioinformatics through predictive analytics technology enables solutions for medical treatments. The authors researched medical nanotechnology-related papers by investigating Scopus, Google Scholar, ResearchGate along with additional research platforms. The study investigates all applications of nanoparticles throughout medical practices. The medical applications of nanotechnology form the core focus in this research work. The second section introduces the medical aspects of nanotechnology by discussing its medical features together with its properties. The steering of nanotechnology development in specific domains requires collaboration between experts from academic, governmental and public sectors. This research evaluates numerous medical applications which nanotechnology can enable. The endocrine system regulates multiple body processes through its control mechanism while diabetes along with thyroid problems and Cushing's syndrome and obesity develop due to its disturbances. Close to fifty percent of participants developed fresh endocrine conditions leading to an overall medical diagnosis rate of 47.4% without treating type 2 diabetes mellitus. Nanotechnology has created new investigative possibilities for studying disease causes and treatments because its atomic and molecular particle manipulation approach. Reaching the end goal in developing nano-biosensors for endocrine treatment requires them to automatically detect minor hormone fluctuations while restoring balanced body system. The unique surface character together with reduced dimensions of nanoparticles makes them valuable agents for targeted drug transportation and more sensitive sensor design. Nano-scale drug delivery carriers made from lipids and polymers together with carbon and metals demonstrate superior performance compared to traditional delivery systems. Nanoparticles serve medical benefits as hydrogels for insulin delivery as well as wound treatment while providing superior outcomes compared to traditional endocrine diagnosis and management methods. The bioactivity together with targeted delivery of inorganic nanoparticles experiences enhanced performance through inclusion of selenium NPs. Research indicates that insulin delivery through gold nanoparticles has the potential to succeed. The incorporation of lipid and polymeric NPs along with mesoporous silica NPs gives healthcare professionals a way to protect medications from gastrointestinal destruction for effective glycaemic level management. Thyroid procedures have increasingly adopted carbon nanotubes (CNTs) during the recent period. Engineers find special attributes of diagnostic and therapeutic systems attractive because these systems include nanoparticles. The development of drug formulations through nanoparticle technology has established medical opportunities for treating resistant medical conditions. Size definitions for nanoparticles extend from 100 to 500 nm with certain exceptions from this range. Nanoparticles become smart systems when their size combination joins with surface modifications to their base material. The stealth-enabled systems have storage space for both therapeutic and imaging agents. These systems provide therapeutic drug containment and regional drug delivery strategies through controlled medication release systems. By continuously delivering medication through this specific system patients become more likely to follow their prescribed treatments and encounter lower numbers of adverse drug reactions. Nanotechnology advances both diagnostic assessments and exhibits potential to treat cancer in combination with AIDS while addressing multiple other healthcare conditions.

Keywords: Nanotechnology, Properties, Healthcare, Diagnostic, Medical Domain

Introduction:

A practice that utilizes phenomena measured at nano-levels in the research, operating, making, and implementation of structures and materials along with devices and systems defines modern nanotechnology. During his 1959 talk about molecular and atomic level construction physicist Richard Feynman first introduced nanotechnology. As a new approach to medical research, nanotechnology has recently gained the reputation as the most exciting technological development of the 21st century. Greater governmental investment in nanotechnology R&D over the past decade is evidence that this technology will bring about a new age of productivity and wealth [1-3]. Industrial capacity and quality can be increased, and the economy can see a boost, all thanks to nanotechnology. Thanks to this development contemporary life retains a new character which benefits the entire social structure. This development would lead to substantial transformations in how people live and the economic structure and national organization of the nation. Through the ages human beings have continuously looked for healing solutions which reduce medical pain and treat injuries and sicknesses. Expert research shows that the achievement of this goal requires nanotechnology applications in healthcare systems. These medical applications use engineered molecular nanodevices along with nanostructures to achieve human biological system monitoring as well as control and production and repair and protection. Nanotechnology could create a revolutionary medical research breakthrough that enables the creation of a new human flourishing sector. Nanotechnology demonstrates effective alignment between three main application areas of diagnosis and therapy and prevention. Among its multiple complications this technology particularly changes the body deliberately. Nanodrugs exhibit improved bioavailability together with side effect elimination while providing therapeutic medicine better absorption through enhanced efficiency. The brain functions like a highly selective membrane barrier, allowing only molecules with a high partition coefficient to enter and leave [4, 5]. This membrane has lately been utilised as a mechanism for transporting medication using nanoparticles. Inhaled nanoparticles can get through the brain's protective barriers. Traditional treatments for vascular thrombosis are typically ineffective because of their short plasma half-life, numerous side effects, and rapid drug wash-outs. Overcoming this limitation could be achieved by immobilising a particular quantity of an agent in a drug delivery system, which would improve the stability and even half-life of the encapsulated medicament. Polymeric nanoparticles receive their production from liposomal nanocarriers and hold attributes of biodegradability as well as biocompatibility. Molecular tools together with human body knowledge have enabled medical advancements that protect and advance human health through illness detection and injury response for treatment or prevention and pain relief systems. Furthermore these scientific discoveries serve additional purposes [6, 7]. Almost every present nanotechnology commercial application in medicine focuses on medications. New action modes can be incorporated into pharmaceutical delivery systems while pharmaceutical substances become both more accessible through better distribution networks and more effective through targeted delivery. The field of nanotechnology will employ nanoprobes and integrated sensory nanoelectronic systems and multifunctional chemical structures for medical purposes like disease targeting and drug delivery. Nanotechnology has already achieved outstanding success in enhancing drug delivery systems. Imaging along with intracellular targeting and regulated gene release can improve with specific chemical use while also making it possible to target and enter pharmaceuticals into cells. Doctors would obtain better control of treatment doses because they can track and advance how medications affect both sick cells and cancer cells. Nanometric therapies can be optimized to destroy diseased cells without harming other tissue when combined with personalized treatment. Scientists have achieved early advancements for developing cells into a possible treatment method for spinal cord damages. Human brain cancer detection along with measurement uses three methods including enzyme-sensitive magnetic nanoparticles, intelligent nanoparticle samples which act as intracellular drug carriers for treatment products and gene expression monitor points. Life sciences research advances because nanotechnology enables new developments in healthcare applications. The manipulation of atomic-scale objects can deliver significant medical advantages to many aspects of healthcare which embrace diagnostic tools along with disease tracking mechanisms and surgical execution and regenerative medicine applications and vaccine production techniques and drug delivery platforms respectively [8–10]. Cutting-edge research tools enable scientists to create new medications which enhance the treatment of numerous diseases. The delivery of medication to body cells with nanotechnology represents one method to minimize failure and rejection occurrence. The second part of this section details the various methods of categorizing nanotechnology-based materials that serve medical purposes. Third, we will list the features and characteristics of nanotechnology and their medical applications. Lastly, we will list the current and future uses of nanotechnology in medicine.

Critical Role of Nanotechnology in Healthcare:

Nanotechnology together with nanodrug discoveries exists across large scientific and practical domains. Progress in nanomedicine allowed medicine to ascend to a higher level that delivers extensive medical perks. Medical science needs immediate research about various applications of nanotechnology to medicine. Medical researchers continue their active investigation into therapeutic genes used for nephrology conditions together with cancer treatments and heart disease therapy. Nanotechnology and nanoparticles together have shown excellent potential to create better quality treatment methods compared to traditional methods which have evolved significantly. Gene therapy stands as a significant medical problem that nanomedicines have successfully addressed. Multiple investigations have studied viral vectors because of their potential as drug delivery platforms. The delivery of accurate medicine to patients depends on research-developed nanobots which target particular cancer cells while operating within smart tablets. The robots transfer information which researchers receive [11, 12]. Nanotechnology offers in-vitro diagnosis through less expensive and easier to use diagnostic alternatives that replace traditional diagnostic methods. The devices show promise to integrate nanoparticles that work as molecular imaging agents respectively detecting genetic and functional attributes of tumor cell. The application of functional nanotechnology leads to coatings that use nanomaterials including carbon black as well as silicon dioxide and iron oxide and zinc oxide and silver and titanium dioxide and other substances based on specific requirements. The physio-chemical characterization and safety analyses of medical devices containing nanosurfaces or nanomaterials become more effective using specific evaluation tools as per references [13, 14]. Modern advancements in energy storage systems together with sensors and new materials depend heavily on scientific discoveries. The combination of small nanoparticle dimensions and elevated surface-to-volume ratio enables them to have excellent drug absorption capabilities which permits quick bloodstream drug transportation. Nanoparticles exhibit unique qualities due to their expanded surface area allowing them to improve their medical applications as well as their magnetic properties while enhancing their optical manifestation and mechanical strength and catalytic action. There exist three definable categories of nanoparticles which are organic, inorganic, and carbon-based nanoparticles due to their chemical structure. A specified size, such as a radius of less than 100 nm, is used to synthesise organic nanoparticles, which can contain proteins, carbohydrates, lipids, and other organic compounds. Inorganic nanoparticles demonstrate stronger advantages over organic ones through their freestability combined with non-toxicity and organism compatibility and being hydrophilic. The group of nanoparticles that excludes organic materials includes metal salts and oxides and elemental metals among others. Fullerenes along with carbon nanotubes make up the nanoparticle group that also contains graphene and multiple derivatives of carbon nanoparticles [15–18]. These materials have attracted interest from multiple industries including biomedical applications due to their remarkable features such as chemical along with mechanical and electrical and thermal and structural properties. Users can benefit from understanding that nanoparticles maintain the chemical properties which exist in their bulk form when selecting particles for various applications. The heat response of nanoparticles reaches therapeutic cancer cell destruction temperatures after light exposure. Numerous scientists predict nanoparticles introduced into bloodstream systems might potentially become cancerous tumors. The smart pills with ingestible sensors permit treatment dosage control by sending control signals through the body remotely. Although nanomedicine operates extensively in medical practices it faces the same basic obstacles that appear in all pioneering technological breakthroughs. The cost-effectiveness of nanotechnology environmental influence greatly depends on reducing its quantity that builds up inside biological tissues and organs [19, 20].

Future promising domains for nanotechnology's use in healthcare:

Nanotechnology enables small portable devices to accept samples before analyzing them quickly which results in rapid procedure completion. The upcoming in vitro diagnostic testing requires bigger samples and biosensors. Special combination formulations of nanoparticles and iron oxides and polymers can boost imaging capabilities to detect genetic disorders and tumors and various diseases earlier while using minimal effective concentrations of diagnostic medications. Nanomedicine faces identical safety-related and privacy-related issues that plague all branches of biotechnology. The robust antibody-antigen bonding delivers high sensitivity thus making immunoassays appropriate tools for this function [21]. The semi-continuous monitoring capability together with statistical rigidity through repetitiveness makes regenerative immune sensors a promising new solution. Clincial staff needs to determine the effects of nanomedicine systems despite being a recent development in cancer treatment approaches.

Treatment and Diagnosis of Endocrine Disorders through the Use of Nanotechnology:

The endocrine system is comprised of many glands that release hormones, which are crucial for controlling various bodily functions. These glands could be fully formed organs or only a collection of cells and tissues. Diabetes, thyroid issues, Cushing's syndrome, and obesity are just some of the conditions that can arise from an imbalance in the endocrine system. Although these disorders do not yet have a cure, there are medications that can be used to keep hormone levels as close to normal as possible, which can help regulate blood pressure. Excluding type 2 diabetes mellitus, the total incidence of endocrine illnesses was determined to be 47.4%. In 18.1% of patients, primary hypothyroidism was diagnosed; in 1.9%, pituitary disease; in 0.8%, Cushing syndrome; and in less than 1%, other endocrine disorders were detected. Surprisingly, 16.3% of patients recently diagnosed with an endocrine illness were also identified in the study. A study that looked at the frequency of endocrine abnormalities in obese people revealed that 14% of those people had hypothyroidism, and another 14.6% had subclinical hypothyroidism, a milder version of the condition [22-24]. Thyroiditis, diabetes, obesity, decreased insulin responsiveness, metabolic syndrome, osteopenia, osteoporosis, dyslipidaemia, erectile dysfunction, and mild to moderate hypovitaminosis D are among the many endocrine illnesses that affect the American population. Certain populations seem to have higher rates of some of these illnesses. According to the latest research, endocrine diseases are more common in people with Down syndrome in the US compared to non-Down syndrome individuals of the same age and gender. There are huge health and financial ramifications to these disorders because they impact at least 5% of American adults. Medications, diagnostic imaging, and illness detection have all benefited greatly from nanotechnology's incorporation into these fields within the past decade. The study and use of nanotechnology focusses on the manipulation of nanoparticles, which are atomic and molecular particles with a size between one and one hundred nanometres. According to the Royal Society, these particles outperform bulkier materials when it comes to localising cells due to their distinct physical, chemical, biological, size distribution, and shape characteristics. Nanoparticles of noble metals, magnetic nanoparticles, and quantum dots have all found applications in the pharmaceutical and biomedical fields, particularly in drug administration and the detection of metal ions, proteins, and nucleic acids in biological markers. However, new advances have rendered these technologies obsolete. There are several applications for nanomaterials, and one of them is in biological systems [25, 26]. Diseases that affect the endocrine system include diabetes mellitus, infertility, obesity, thyroid and parathyroid issues, and others. Researchers are striving to develop more effective treatments for endocrine diseases while keeping the seriousness of the issue in mind. The application of nanotechnology to the treatment of endocrine diseases has shown encouraging results, however this area of study is still in its early stages. Nanonetworks, which are units of interconnected nanomachines that communicate chemically, constitute this internal monitoring system. Nanotechnology has recently made great strides, opening up new possibilities for integrating diagnostics and treatment on a single platform, as well as for targeting and modifying cellular behaviour at the nanoscale. To lay the groundwork for theranostics, nano-therapy has shown encouraging results, halting the progression of treatable diseases that would otherwise be fatal due to a lack of timely diagnosis and treatment. Though some nanoparticles have found imaging applications already, others may one day become theranostic, meaning they can serve two roles at once [27, 28]. The term "theranostics" was coined to describe individualised therapies for a wide range of medical conditions. Nanoscale carriers made of lipids, polymers, carbon, or metals are being developed to replace conventional drug delivery systems, which have several limitations.

Properties of Physicochemistry Affecting Theranostics:

It is already commonly known that the way that nanoparticles (NPs) interact with cells is greatly influenced by their physical characteristics. Size, shape, and the direction of the surface groups are important characteristics, though. The high surface area-to-volume ratio of nanoparticles, which range in size from 1 nm to 100 nm, makes them extremely reactive and able to penetrate bodily fluids and tissues. Within biological systems, their endocytosis, dispersion, retention, and removal are influenced by their surface area and size. Clathrin-coated vesicles internalise nanoparticles smaller than 200 nm, whereas caveolae-mediated endocytosis is used for larger ones. Smaller particles reach immune cells by the phagocytotic pathway, which phagocytoses nanoparticles. Drug activity can be increased by engineering liposomes for optimal uptake by mammalian cells. Nanoparticles' intracellular localisation varies according to their size; larger particles stay in the cytoplasm while smaller ones get to the nucleus. Drug penetration via the blood–brain barrier and brain targeting are both successfully accomplished by polymeric nanoparticles (20–200 nm). Because of their large surface area, PEGylated nanoparticles increase medication stability and circulation time. The reactivity and function of nanoparticles are largely determined by their surface chemistry, which includes their charge and any attached chemical groups. Cellular absorption is improved by surface modifications of nanoparticles, such as conjugating DNA to cationic liposomes or covering rod-shaped gold nanoparticles (AuNPs) and DNA with lipid layers. Because of their lipid coatings, liposomes and micelles make it easier to distribute nanoparticles inside cells. Silicon dioxide (SiO2) surface modification is necessary for silicon nanoparticles (SiNPs), which are utilised in optoelectronics, to increase their hydrophilicity for biomedical applications [29–31]. The surface characteristics of zinc oxide (ZnO2) nanoparticles, which are frequently included in sunscreen, have been modified to lessen cytotoxicity while maintaining UV protection. Amphiphilic phospholipids make up liposomes, which resemble the plasma membrane and facilitate efficient drug administration via membrane fusion or receptor-mediated endocytosis. The pH of the delivery environment has a major impact on how well nanoparticles work, especially when it comes to their surface chemistry. This idea is used to start the release of drugs into the acidic tumour microenvironment. For instance, it has been shown that AuNPs capped with carrageenan oligosaccharides can release epirubicin in acidic environments, which causes HCT-116 colorectal cancer cells to undergo apoptosis. The behaviour of nanoparticles in aquatic biological systems is greatly influenced by their surface properties, which also have an impact on their reactivity and effectiveness of delivery. Because of these characteristics, nanoparticles can be used in medication delivery systems, biomedical sensors, and coatings for medical implants. The use of titanium implants functionalised with silver nanoparticles (AgNP), which have antibacterial qualities and prevent postoperative infections, is a relevant example [32, 33]. The present medical industry includes liposomes as one of its most remarkable contemporary scientific breakthroughs. Medical medications travel through illness battles by using these vesicles which have an aqueous core protected by a lipid bilayer. The incorporation of cholesterol strengthens phospholipid bilayer resistance to protect nanoparticles such as AuNPs and pharmaceutical drugs because they depend on lipid coverings which create compatibility with cell membranes and enable cellular entry. Liposomes display their true brilliance by using phospholipid heads as the basis for adding numerous chemicals that enable precise targeting capabilities. One notable application involves the PEGylation process that confers phagocyte protective covering to liposomes which leads to better availability and effectiveness. Liposomes represent advancements of both biology and technology for healing purposes while showing human creativity at its peak. The procedure allows scientists to incorporate active groups including folate and monoclonal antibodies which function as cellular-targeting signals in complex targeting systems. Folate shows a preference for cancer cells because of elevated folate receptor expression on cancerous cells. Monoclonal antibodies deliver tailored delivery through targeted administration methods because they can attach themselves to specific receptors and surface antigens. There is an improvement in delivering medications or nanoparticles to tumor cells for selective elimination through the surface conjugation of these substances to nanoparticles.

Diagnostic Tools Based on Nanomaterials:

For morphological and functional evaluations, imaging organs and tissues while they are still alive, or in vivo, is necessary. In addition to the pituitary, adrenal, thyroid, and reproductive glands, it can aid in the diagnosis and analysis of tumours affecting the pancreas, skeletal system, and other endocrine glands. Common imaging modalities utilised in ultrasonography include X-ray computed tomography, magnetic resonance imaging, and contrast agents or intrinsic contrast. These imaging methods reveal the anatomical and physiological characteristics of tumours or glands. Neuroimaging techniques including as scintigraphy, positron emission tomography (PET), and single-photon emission computed tomography (SPECT) can be employed to conduct molecular and functional diseases imaging. These imaging techniques assess biochemical and metabolic markers by use of radionuclide-based agents that are administered to the skin of the patient. A new alternative to conventional imaging methods has developed in the field of endocrinology: optical imaging using visible or near-infrared wavelengths. Examples of fluorescence imaging techniques used in endocrine surgery include indocyanine green and parathyroid autofluorescence. Particularly, there have been cases of thyroidectomy or adrenalectomy guided by fluorescence, with the latter allowing for better localisation of the parathyroid glands—which are otherwise hard to see and sometimes removed accidentally together with the thyroid—during the removal process. When locating parathyroid tissue during surgery, label-free autofluorescence imaging is a great tool to use [34, 35]. The method is useful for preserving parathyroid glands during surgery, but it has several limitations, such as a 3 mm maximum penetration depth and no information on tissue perfusion and oxygenation. The ability to link spherical nanoparticles to biomarkers that react exclusively under specific pathological conditions makes them a common diagnostic tool for endocrine illnesses. This versatile nanoparticle can detect and track specific analytes or illnesses by acting as a biological label. Methods for detection encompass electrical impedance spectroscopy, surface plasmon resonance, peak wavelength shifts, light absorption measurements, and electrochemical or electrical alterations. Among the many D nanomaterials utilised in diagnostic instruments, gold nanoparticles (AuNPs) stand out for their catalytic characteristics, significant colour changes according to diameter or surface, and excellent bio-affinity. Due to their properties, AuNPs are ideal for application in optical and electrochemical PoC devices. There are numerous shapes and sizes of AuNPs, including nanospheres, nanorods, nano-shells, nano-cubes, nanocages, and branched forms. Their sizes range from 1 nm to 8 μm. The synthesis of AuNPs in a wide range of sizes and geometries is straightforward. Functionalisation with biological molecules like as medicines, DNA, and ligands is possible on their huge negatively charged surfaces and abundant surface area. Shape, size, and aggregation status determine the distinctive optical and electrical properties of AuNPs, especially through plasmon resonance. They are perfect for bimolecular detection, chemical and biological sensing, molecular imaging, protein and cell labelling, and delivering medicines, genes, antigens, and antibodies into cells because of this quality, which makes them very sensitive to optical detection techniques. One type of one-dimensional nanomaterial is the one-nanometer-thick single-walled carbon nanotube. This type of material grows in a straight line. This trend in development is the inspiration for the moniker "one-dimensional nanomaterials" [36, 37]. The shape of these nanomaterials greatly affects their mechanical strength, absorption wavelengths, and applicability, and their length can vary from hundreds of micrometres to a million times longer. On the other hand, 1D nanomaterials are difficult to develop and necessitate meticulous synthetic pathways to guarantee their uniformity. An new method for ECG monitoring was developed by Mostafalu and Sonkusale employing 1D nanomaterials in paper substrates. Electrodes that function in dry environments without an electrolytic gel were created in their work by inserting platinum, nickel, and copper nanowires into paper substrates. The nanowires' massive surface area enables high-quality electrode responses with impedance measurements ranging from 100 to 1 K. The use of an electrolytic gel, which rapidly dries up and deteriorates upon transfer, is not necessary with this technique. The paper electrodes were effective as cathodes in an acidic battery and may have other medical uses as well. 36 After rinsing chewing gum with ethanol and water, Darabi et al. created a new use for carbon nanotubes (CNTs) by combining the gum with a CNT solution. By stretching and folding the resultant mixture, the CNTs were aligned in one direction, enabling the gum to detect humidity through electrical resistance measurements. In addition to revealing the device's potential as a breath sensor, this method also revealed the device's potential as a motion sensor. Biting issues, dry mouth, pulsations, and other chemical targets could be detected with this technique for point-of-care diagnostics. Nevertheless, there are certain problems with the usage of CNTs as a sensing material. Firstly, CNTs are currently considered cytotoxic nanomaterials. Secondly, the reaction of the device is detected by electrical circuits.

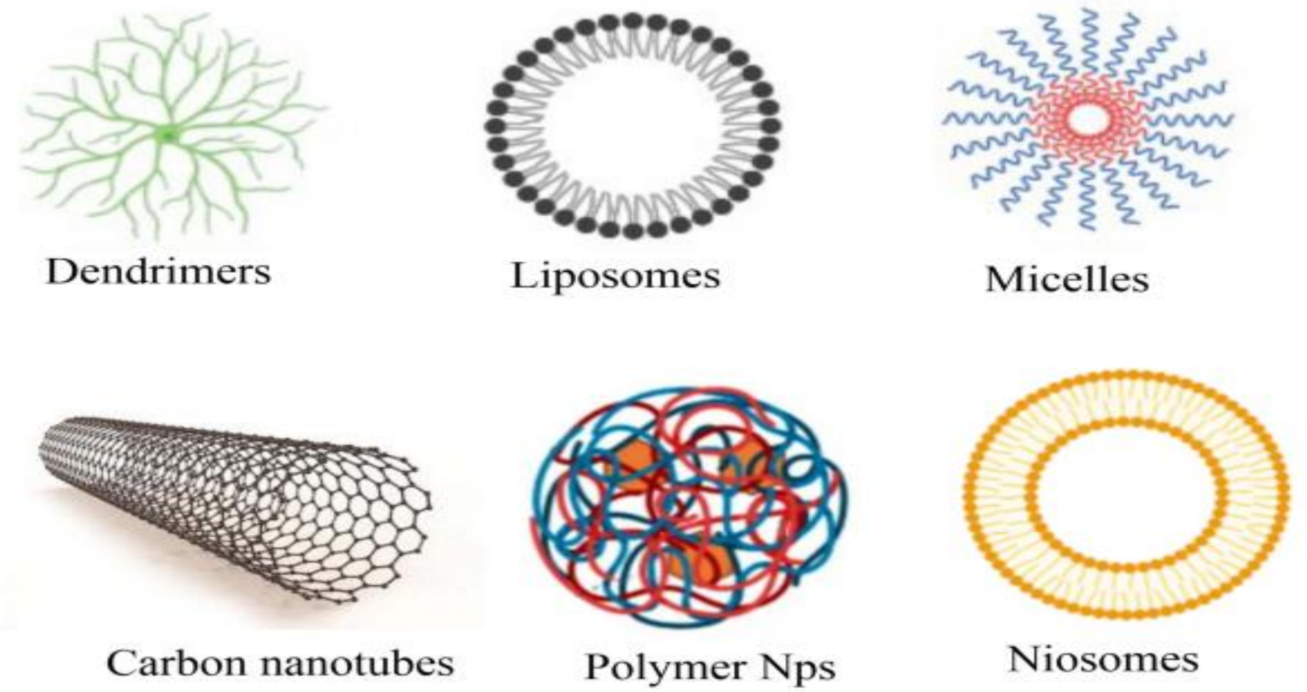

Figure 1. Potentially useful nanomaterials for metabolic diseases.

Metallic Nanomaterials

The use of metallic nanoparticles in the treatment of metabolic diseases appears promising. 58 Exposure to ultraviolet light causes quantum dots, a sort of nanoparticle, to glow. These quantum dots can detect tumours by illuminating malignant cells when they target them. Recent research has investigated the possibility of doxorubicin-loaded magnetic poly-(D, L-lactide-co-glycolide) nanoparticles conjugated with antibodies. The purpose of incorporating DOX into PLGA nanoparticles is to create magnetic nanoparticles that can specifically target cancer cells. When it comes to killing breast cancer cells, the antibody Herceptin is head and shoulders above the competition. 59 Infectious and inflammatory illness management is an area where nanoparticles shine. The viral infection known as hepatitis is a lifelong chronic illness. Nanoparticles, and gold nanoparticles in particular, have shown great promise in the diagnosis of this illness [38]. The development of gold nano-protein chips for the detection of hepatitis antibodies has resulted in a very effective diagnostic tool. One frequent method of inducing an antibody response in patients is by the use of DNA vaccines coated with SiO_2 (LDH) nanoparticles. 60 One such use of nanotechnology is the reduction of inflammation in the bone. Specifically, metal nanoparticles, thanks to their increased surface area, have shown to be very useful in the production of osteoblasts. For this function, titanium is often utilised. To alleviate inflammation in the joints, PLGA particles are mixed with superparamagnetic iron oxide nanoparticles. Nanotechnology also has great potential for treating skin infections. This is achieved by using nitric acid-coated nanoparticles, which aid in tissue regeneration and increase the skin's ability to absorb anti-inflammatory medications, and by interacting directly with thrombin, which is a protein. Nanoparticles of gold (AuNPs) bound to various trastuzumab antibodies are engineered to zero in on SKBR-3 breast cancer cells and their HER-2 receptor. These gold-HER particles double the cytotoxicity of trastuzumab when they attach to the HER-2 receptor and are taken up by cells.

Hyperglycemia and Nanotechnology

Because of irregularities in insulin secretion and activity, diabetes mellitus affects people of all ages and is a prevalent illness. The kidneys, eyes, heart, nerves, and blood arteries are among the vital organs and systems that might suffer damage from hyperglycemia, a consequence of diabetes. Imbalances in the metabolism of lipids, carbohydrates, and proteins lead to insulin resistance and insulin insufficiency, the hallmarks of diabetes mellitus. Damage to pancreatic beta-cells by an autoimmune mechanism causes these metabolic abnormalities. Insulin resistance and inadequate levels characterise diabetes mellitus. As the illness worsens, effective treatment that lasts a long time is necessary. Mortality, morbidity, and healthcare expenditures have all been inflated due to the epidemic of diabetes mellitus. Both the potential benefits and drawbacks of nanotechnology have demonstrated a link to diabetes. On the one hand, nanoparticles can serve as hydrogels that promote wound healing by utilising bioactive molecules like growth factors or proteins. On the other hand, there are unintended consequences of nano molecules that harm glucose profiles. The fast expansion of transdisciplinary nanotechnology research pertaining to diabetes is a direct result of the substantial epidemiological impact that the disease has on the overall population [39]. It can be used with both conventional therapeutic and diagnostic protocols and state-of-the-art CADD cheminformatics technologies. Improvements in insulin dosage and general diabetes care, as well as more precise readings from glucose sensors, might have a profound impact on the lives of those living with diabetes. We still don't know the answers to many important questions in this area, such as how long it takes for an exposure to have an effect, how a person's genetic makeup interacts with environmental factors, and what exactly is the relationship between endocrine disruptors and their effects on humans and animals. In addition, particular anti-diabetic prescription regimens for individuals with type 2 diabetes, regardless of age, lack sufficient and high-quality evidence. The effectiveness of NPs in diabetes is believed to be due to a number of processes. One of these is the focus on specific enzymes. One of the most important ways to treat diabetes is to suppress the enzymes alpha-amylase and alpha-glucosidase, which play critical roles in the metabolism of carbohydrates. Amylase and glucosidase inhibitors aid in glucose management by blocking carbohydrate hydrolysis [40]. When ingested alongside starchy foods, an amylase inhibitor reduces the usual spike in blood sugar levels. Multiple in vitro and in vivo investigations have confirmed that AgNPs inhibit alpha-amylase.

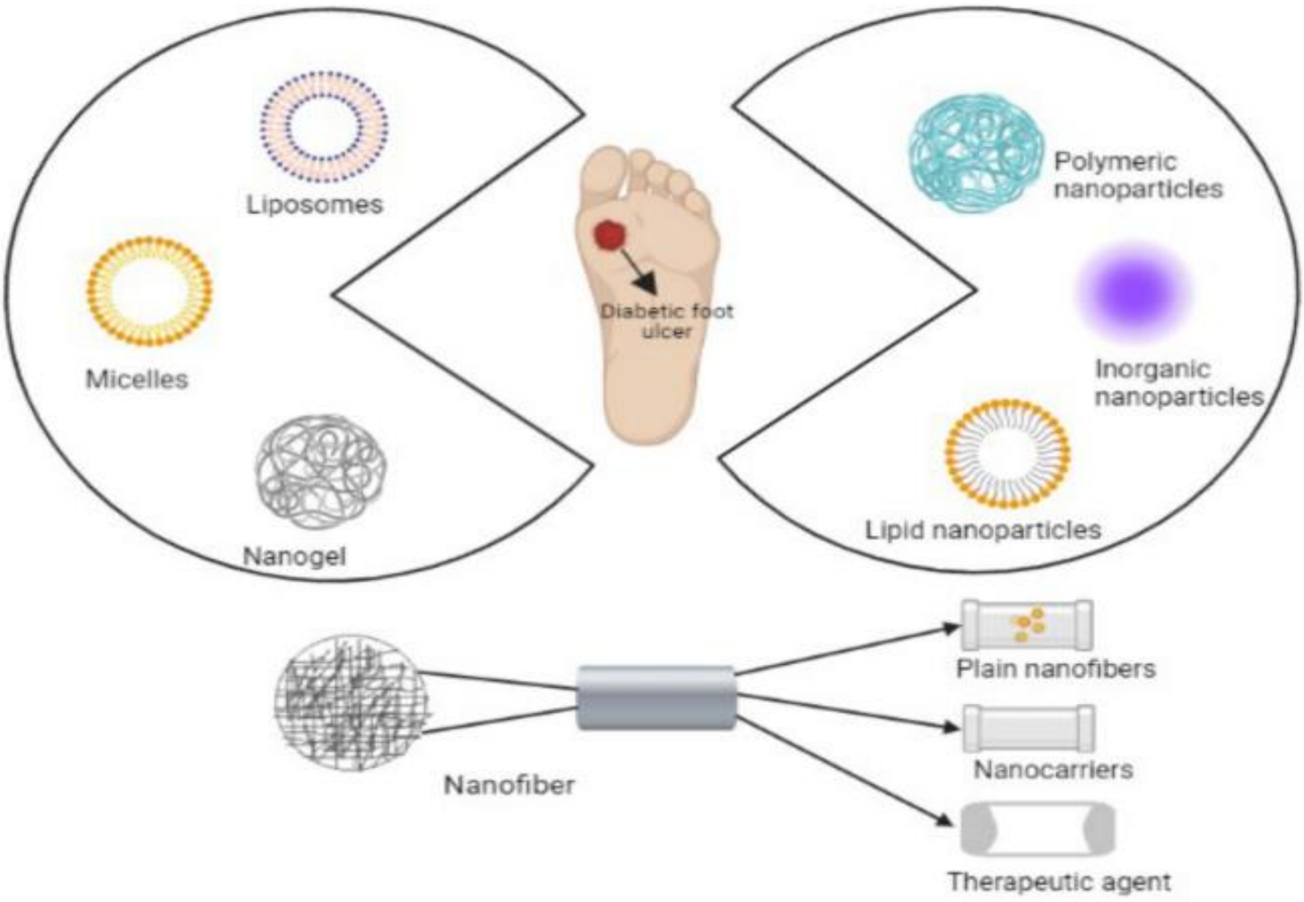

Figure 2. Various types of nanocarriers used to treat chronic wounds are shown in this schematic. These include polymeric, inorganic, and lipid-based nanoparticles, as well as self-assembled nanocarriers like liposomes, micelles, and nanogels. Also, nanofibers could be seen as a way to encapsulate medicinal substances or nanocarriers.

Nanoparticle methods for medication delivery: potential applications:

If one looks at medical practice from the past century compared to the present, they will see countless innovations that have helped treat diseases that were once thought to have no cure. There are a lot of new drugs that can treat serious diseases, but some of them have such bad side effects that the benefit isn't always worth it. However, there are medications that work well in a controlled laboratory setting but are rendered practically useless when administered orally to humans because they are unable to withstand the endogenous enzymes found in the GI tract. Even though we've come a long way in discovering new therapeutic targets and improving our drug molecule designs, we can still do better when it comes to drug delivery systems and targeting. There has been unparalleled interest in nanotechnology, and the production of nanoparticles in particular, across several scientific disciplines during the last several decades. The formulation and delivery of medications have been transformed by the ingenious utilisation of nanoparticles. Applying engineering and manufacturing techniques at the molecular level, nanotechnology is a multi-disciplinary scientific field. Nanoparticles, made possible by the application of nanotechnology to medicine, can imitate or change biological processes.

Drug compositions based on nanoparticles are essential:

Numerous important considerations require the immediate adoption of nanoparticles as diagnostic tools diagnostic tools and therapeutic agents as well as agents to enhance medication delivery. The existing oral and injectable pharmaceuticals were not engineered with optimal drug formulations in mind. The delivery of nucleic acid and protein-based products requires entirely new carrier systems to both improve their effectiveness and stop their premature breakdown. Nanoparticle dimension determines the effectiveness rates of medication delivery systems apart from intravenous administration and solution delivery. Due to their low surface area to volume ratio particles improve their ability to dissolve and become available in the body. Such particles penetrate three vital biological pathways involving the pulmonary system and endothelial cell tight junctions within the skin and the BBB tissue. The development of nanoparticles composed of biodegradable and non-biodegradable polymers for specific drug delivery while increasing medication availability has heightened their general interest because of their single-dose controlled release capabilities. The structural modification enables nanoparticles to avoid destruction from body enzymes. The market growth of pharmaceutical sales happens through expanding drug delivery technology developments. Today's pharmaceutical market generates new medication formulations through innovative drug delivery systems produced by pharmaceutical manufacturing companies. Patients will benefit from these new formulations that create a robust market force which drives the development of highly efficient delivery methods. Organizations can gain substantially from investing in research and development for their proprietary assets while they receive additional motivation to do so once protected exclusivities expire. Pharmaceutical businesses obtain advantages from this modern technology by reviving medications with low bioavailability and solubility together with significant toxicity and adverse effects that made them unmarketable in the past. The laboratory of MIT professor Robert Langer produced a new publication which reviews numerous polymeric formulations that healthcare providers use to administer medications.

Cancer therapy:

Chemotherapy has saved countless lives, but it comes with severe side effects that affect the whole body because it is not targeted specifically to cancer. Because of its complexity, cancer is best understood as a sickness of diseases. Cancerous cells are characterised by unchecked cell division and proliferation. The primary goal of modern chemotherapy is to eliminate any cells that divide quickly. Unfortunately, this treatment has life-altering negative effects since it kills out the body's other fast-growing cells, too. These cells are found in places like the hair follicles and the intestinal epithelium. A new approach to chemotherapy has been opened up by the discovery of nanoparticles. To minimise harm to healthy tissues and organs, nanoparticles can be precisely engineered to deliver drugs only to tumours or specific cell populations. Various systems that offer this treatment have been put through their paces. Another alternative for the delivery of chemotherapeutic drugs is via micelles and liposomes. The hydrophobic core and hydrophilic shell of micelles make them an excellent vehicle for solubilising medications that would otherwise be insoluble. Through PEGylation of the micelles an enhanced passive transport becomes possible through fenestrated tumour vasculature and inflammatory tissue which results in greater drug accumulation in tumours. The system Genexol-PM (paclitaxel) receives licensing for breast cancer patients while additional anticancer medications proceed through active clinical trials. The ADME profile of dendrimers depends on many structural features because these branched macromolecules contain multiple accessible functional groups for pharmacological and targeting or imaging agent attachments. A polyfunctional dendrimer system enables researchers to transport methotrexate anticancer medicine in vitro and use fluorescein for imaging along with folic acid for localization. The combination of biocompatible materials and PEGylation, acetylation, glycosylation, and different amino acids surface modification on dendrimer-based nanoparticles enhances the therapeutic ratio of cytotoxic drugs [41]. Within the traditional set of nanoparticles employed for cancer therapy carbon nanotubes emerged as one of the latest discoveries. Single-walled and multiwalled CNTs function as the two allotropic carbon nanotube types that form cylindrical structures with single-layer or multiple-layered concentric cylinders. The hydrophobic nature of carbon nanotubes makes them perfect for storing medications which resist water because they have a hollow interior. The extensive surface area enables researchers to modify the components on the surface in order to bond with specific cancer receptors as well as contrast agents. The spherical molecule known as Buckminsterfullerene C60 along with its variants becomes part of cancer treatment research. The ability of fullerene C60 to accept six electrons makes it an outstanding ROS scavenger. Scientific studies have demonstrated Nano-C60 fullerene nanocrystals enhance the deadly properties of chemotherapeutic drugs therefore more exploration of Nano-C60 chemotherapy use as an adjunct is needed. Research suggests that the tumor cell interaction of C60 + Dox complex occurs through two mechanisms including direct tumor cell attachment along with immune system involvement.

Nutraceutical delivery:

The medical field classifies nutraceuticals as standardized food elements derived from foods which show specific health benefits. Patients use nutraceuticals alone or as supplements with their allopathic medications to obtain additional health benefits as well as decreased susceptibility to particular chronic illnesses. The bioavailability of orally consumed nutraceuticals depends on the relationships between food formations and water solubility levels and degradation/metabolism and epithelial permeability rates. Lipophilic compounds make up most nutraceuticals because they include polyunsaturated lipids as well as various phytochemicals together with fat soluble vitamins A, D, E and K. Nanotechnology supports every aspect of research through its compositions of nanoparticles for improving nutraceutical dissolution methods. Research indicates that Curcumin (diferuloylmethane) stands as the most popular and investigated among a large group of nutraceuticals that demonstrate anti-inflammatory combined with antioxidative and antiapoptotic and antiangiogenic effects. Various methods such as liposomes phospholipid vesicles and polymer-based nano-formulations have been developed to solve this challenge because ketoconazole is practically insoluble in water with poor bioavailability rates. Researchers discovered that curcumin supplemented with piperine resulted in ninefold higher oral bioavailability when compared to single curcumin administration. Rats and healthy human volunteers displayed an area under the curve (AUC) enhancement rate of 40 times in rats and 27 times in human volunteers when examined through curcumin colloidal nanoparticles called Theracurmin compared to curcumin powder alone. Plants contain the important polyphenolic compound resveratrol although it maintains its highest concentrations within muscadine grapes and in both species of grape vines Vitis vinifera and Labrusca. The compound offers anti-inflammatory along with cardioprotective and antioxidant potential and shows anti-cancer effects. The body quickly eliminates resveratrol because this compound shows low water solubility although its bioavailability remains at a satisfactory level. Two geometric shapes exist for resveratrol and they are known as cis- and trans. Trans-resveratrol functions as the bioactive form yet this substance transforms into cis-resveratrol under photo-exposure. Several nanoformulations of resveratrol were discovered because they improve its pharmacokinetic profile along with bioavailability. These consist of dual nanoencapsulation techniques, liposomes, cyclodextrins, polymeric nanoparticles, zein-based nanoparticles, and nanoemulsions. Solid lipid nanoparticles coated with apolipoprotein E for LDL receptor recognition on the blood-brain barrier recently became available for assessing resveratrol's neuroprotective effects.

Conclusion:

A number of critical physiological processes are controlled by the endocrine system. Many endocrine problems are manageable with drugs that are already available, and their prevalence is significant. Nevertheless, in order to properly diagnose and manage endocrine problems, a comprehensive evaluation is required to identify any undiscovered dysfunctions that may call for targeted medication or even rule out surgical options. By shedding light on disease pathophysiology and treatment options in novel ways, nanotechnology has revolutionised pharmaceutical research and development. Thanks to recent developments in nanotechnology, patients are now able to receive diagnosis and treatment closer to where they live. A wide range of nanostructures, including spherical nanoparticles, dendrimers, micelles, and imaging techniques, are utilised as biosensors and drug delivery systems in diagnostics. Mesoporous silica nanoparticles, gold nanoparticles, and insulin delivery all play essential roles in endocrine disorders; these nanoparticles also have the potential to control diabetes more effectively than existing options by maintaining stable glycemia levels. Solving the problems with conventional drug delivery methods is the creation of nano-sized carriers made of lipids, polymers, carbon, or metals. Different metal-based nanoparticles can impede insulin signalling pathways and insulin production, according to the toxicity of nanomaterials, especially their endocrine disrupting effects. Nanotechnology has great promise for the detection and treatment of endocrine diseases, as demonstrated in recent clinical trials that used nano-sensors to detect diabetic indicators in human biofluids. The creation of nano-sized carriers with dual functions could lead to the development of future theranostic agents. Typically, they are employed in the field of disease management to resolve concerns related to patient safety and compliance that have long plagued conventional NP systems. Researchers are hopeful that further investigation into the use of nanotechnology in the management of endocrine disorders may yield new medicines that are more effective for patients. The use of nanotechnology in metabolic illnesses shows potential, and things are not looking as dismal as they may be, thanks to continuing research and development. A major step forward in the research has been the creation of endogenous nano-biosensors that can detect even small changes in hormone levels and automatically react in a coordinated way to bring them back to normal functioning. More targeted and individualised treatments for many diseases may be possible with the use of nanotechnology in the diagnosis and treatment of endocrine problems. A more tailored approach to treatment, made possible by nanotechnology and the advent of theranostics, might lead to better results for patients. Expensive experiments are often necessary for research on nanotechnology and nanomaterials. With a focus on nanomaterials (NMs), ML has led to advancements in the design of NM structures, characteristics, adsorption, and catalysis. New approaches to creating sustainable nanomaterials and advancements in the field of nanomaterials (NM) were both facilitated by machine learning (ML). It is intriguing to note that NMs, such as liposomes, micelles, and polymeric NPs, can effectively enhance targeted drug dispersion, lower the API concentration, and reduce toxicity. Additionally, the development of an artificial pancreas and continuous glucose monitoring are both made possible by the emergence of smart polymers. Therefore, nanotechnology shows great promise for the future of endocrine disease management, and further study might pave the way for innovative treatments that revolutionise endocrinology. Chemists, physicists, biologists, and pharmaceutical scientists have all played important roles in developing new diagnostic and therapeutic techniques within nanotechnology, making it truly a multidisciplinary science. This analysis makes it clear that nontechnological applications in medicine and drug delivery have created possibilities for safer, more personalised treatment options. A number of fields have benefited from nanotechnology's use, including cancer and HIV/AIDS treatment, noninvasive imaging, and nutraceutical delivery. In the end, scientists can control the size and surface characteristics of molecules to make meds that last longer, require less dosage (sustained release), and penetrate even the most inaccessible areas with more accuracy and precision.

Decelerations

Ethics approval and consent to participate

Not Applicable

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Conflicts of Interest

The authors declare no conflict of interest.

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