Current Advances in Nanotechnology and Medicine

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Abstract

One of the most imperative questions that arise is why we are indulging ourselves in nanotechnology and medicine. The rationale is its size in nanometer range which makes it easy to enter into cells of human body making it beneficial for special types of cell target therapy such as efficient delivery of drugs to the target cell and competent detection of diseases. Studies have come up with one more beneficial factor, that is, the nanoparticles can also protect drug from degradation because of the shield-like properties. The elemental proposition upon which nanomedicine is pursued is nanoparticles, which are introduced into the body as foreign bodies and are subjected to the full armory of the body's defense system labeled with antibody molecules targeting specific cells. Diverse types and forms of nanoparticles are used in medicine. Advances in the area of nanomedicine have come a long way since the time it was envisioned to be studied. The objectives and goal to establish global roadmaps in nanomedicine are guided by the need to take care of life-threatening clinical issues. Nanomedicine has a potential to combat several human diseases including cancer as well as infectious, neurological, musculoskeletal, cardiovascular diseases. In this chapter we will be discussing the ongoing progress of nanotechnology and its application in various fields of medicine.

Keywords

Nanomedicine · Nanoparticles · Liposomes · Magnetic Nanoparticles · Molecular Imaging · NDDS · Quantum dots · Diagnostics · Therapeutics · Regenerative Medicine · Cancer

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1.1 Introduction

We have entered into an era of the notion, "The smaller the better". Nano refers to things that are very small, smaller than the smallest. Hence, in the bare-bone version of definition, "Nanotechnology is the investigation and utilization of structures between 1 nanometer (nm) and 100 nanometers in size" (Logothetidis 2006). One-billionth of a meter is defined as a nanometer which is too microscopic to be seen by any usual optical microscope. Nanotechnology has the potential to transform the way the medical and healthcare solutions are developed and delivered through its application toward the diagnosis, treatments, or prevention of diseases at the cellular level, and hence, the application is termed as *nanomedicine* (Bayford et al. 2017). The two fundamental areas in nanomedicine are nanomedicine-based diagnostics and nanotechnology-based therapies. The quick development of nanoscience in the last few years has given an abundance of information into the biological performance and physicochemical properties of nanoscale materials that can be considered while utilizing nanotechnology for medicinal applications, for example, in atomic imaging applications (diagnostics), thermal initiated annihilation of tumors (therapy), and, furthermore, disintegration of ineffectively soluble medications generally utilized inside the pharmaceutical businesses (Fig. 1.1) (Rizzo et al. 2013). Nanomedicine is defined as the comprehensive examination, control, development, repair, resistance, and enhancement of all human natural frameworks, working from the atomic dimension, utilizing designed nano-devices and nanostructures. Nanomedicine is also known as the science and innovation of diagnosis,

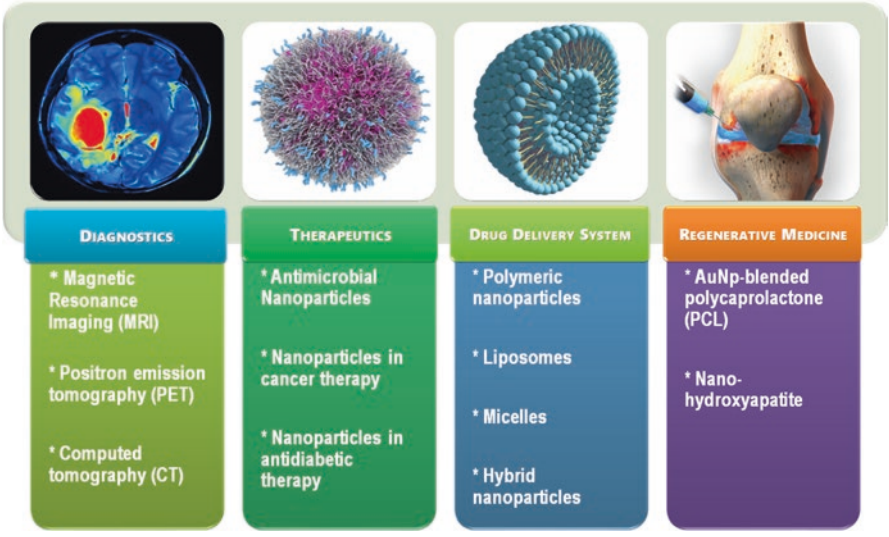

Fig. 1.1 Applications of nanotechnology in medicine. This figure depicts emerging field of nanomedicine which involves various multidisciplinary areas of medicine such as diagnostics, therapeutics, drug delivery system and regenerative medicine etc.

therapeutics, and anticipating infection and awful damage, of assuaging torment, and of safeguarding and enhancing human well-being, utilizing subatomic instruments and subatomic learning of the human body (Saxena et al. 2012).

1.2 Nanotechnology in Disease Diagnosis

With the advancement in the era of clinical diagnostics, a definitive objective is to empower physicians to detect a disease as early of schedule as could be expected under the circumstances. Nanotechnology is required to make detection/diagnosis conceivable at the cellular and sub-cellular level. With the assistance of nanomedicine, early detection as well as prevention, precise diagnosis, effective treatment and follow-up of infections are conceivable (Archakov 2010). Nanotechnology guarantees efficient and incredibly precise apparatuses for in vitro and in vivo diagnostics. The enhanced diagnostics leads to better treatments and improved health outcomes. Nanotechnology has been utilized broadly in the field of restorative diagnostics (Zhang et al. 2018a). Cancer is one field of ailment in which nanotechnology is probably going to have the greatest effect as enhanced diagnostics and treatment. EGFR which is an epidermal development factor receptor present outwardly of their layers where nonmalignant growth cells have significantly less EGFR. Upon binding of gold nanoparticles (AuNps) to an antibody for EGFR (anti-EGFR), the capacity to tie the nanoparticles to the malignant growth cells has been achieved. When bound, the malignant growth cells show distinctive light dissipating and assimilation spectra than favorable cells. Pathologists may utilize these findings to distinguish harmful cells in biopsy tests (Zitka et al. 2012). Certain nanoscale particles are utilized as labels or tags. Point of care and imaging technologies are two specific fields that have the advantage of nanoparticle applications. From the last few decades, imaging has turned into a basic apparatus in the diagnosis of disease.

1.2.1 Nanoparticles for In Vivo Diagnostics

Molecular imaging is outlined as the in vivo visual images, activity, and characterization of biological phenomenon at the molecular and cellular level. Such imaging helps in unfolding the possibility of early detection of underlying diseases and to probe for the stage of disease and, therefore, helps in effective image-guided treatment. This imaging technique frequently includes the employment of imaging probes that turn out signals by means of nuclear reaction together with different molecules to image via sound waves (ultrasound), magnetism (MRI), or light (optical techniques of luminescence and fluorescence) (Miller 2016). Advancement in molecular imaging needs the application of refined probes that square measurable to discover biological processes on the cellular and molecular level. That is when the need of nanoparticles arises considering the point that probes for molecular imaging need to possess certain features for the efficacy. Such probes need to possess the characterization properties to be able to get accumulated at the site of

interest and furthermore and eventually be able to get imaged (Baptista 2014). Different nanosystems, with unique physical and chemical properties, are continuously being proposed with distinct functions and targets. And such nanoparticles-based molecular imaging probes and contrast agents have been studied to be significant over all the other single molecule-based contrast probes. Nanoparticulate-based imaging contrast agents involve the use of appropriate contrast-generating materials such as fluorescent, radioactive, paramagnetic, and super paramagnetic or electron dense (Emeto et al. 2017). These significantly efficient probes have led to the development of plethora of noble metal nanoparticles and quantum dots and also a profusion of nanoparticulate-based contrast agents as micelles, liposomes, polymerosomes, dendrimers, carbon nanoparticles, and magnetic nanoparticles (iron oxides, metal alloys) (Naseri et al. 2018).

1.2.1.1 Magnetic Resonance Imaging (MRI)

MRI is a non-invasive method of anatomic images with spatial resolution which is based on NMR principle and is processed with the help of several NMR active nuclei. However, sometimes these active nuclei (also, termed as inherent contrast) are inadequate for the proper characterization of tissue, and, hence, the use of contrast agents is required (Tognarelli et al. 2015). MRI contrast agents are referred to as T1 and T2, with respect to the relaxation time that they predominantly affect. T1 agents have a propensity of paramagnetic compounds (as lanthanides), and T2 agents are commonly super-paramagnetic agents, as iron oxides. Nanosystem-based contrast agents referred as T1 agents are micelles, liposomes, polymerosomes, dendrimers, and carbon nanoparticles, whereas T2-agents are magnetic nanoparticles (iron oxides, metal alloys) (Sands and Levitin 2004). As MRI contrast agents, several of the nanoparticles have been tested which are FDA approved and are of great relevance such as super paramagnetic iron oxide nanoparticles (SPION). Research and studies are conducted to develop nanoparticles as T1 contrast agents in order to overcome the drawbacks of T2 contrast agents (Kim et al. 2018).

1.2.1.2 Positron Emission Tomography (PET)

PET is a quantitative imaging procedure which uses biomolecule release electrons that interacted with radionuclides emitting positrons. PET imaging is used mostly in early detection of tumorous cells. One of the most widely used imaging probes is the metal oxide nanoparticles which help in the construction of PET imaging (Jones and Townsend 2017). Liposomes have also been used in combination with positron emitting radionuclides for contrast imaging. Furthermore, polymeric micelles and hydrogels are also used for tumor detection and delivery (Silindir et al. 2012).

1.2.1.3 Computed Tomography (CT)

Extensive research is being carried out in the area of molecular imaging which focuses on the development of CT contrast agents. The concentration of contrast agents is required in millimolar for CT imaging of desired organs. Nevertheless, nanoparticle contrast agents can amplify the contrast which reduces the

comparatively high exposure radiation in CT (Goldman 2007). AuNPs have been shown to enhance the visibility xenografted human breast tumors of mm-sized where an anti-Her2 antibody was shown to be 1.6-fold efficiently targeted. There were 22-fold higher uptakes of gold nanoparticles in the tumor fringe recorded. Glucose AuNPs have also been found to act as a CT agent that allows differentiation between inflammatory process and cancerous condition (Cole et al. 2015).

1.2.2 Recent Advancement of Nano-Based Molecular Diagnostics

A number of nanoparticles are being used as diagnostic tools. The foremost technologies are quantum dots (QDs), magnetic nanoparticles (MNPs), and gold nanoparticles (GNPs or AuNps).

1.2.2.1 Gold Nanoparticles (GNPs or AuNPs)

Gold nanoparticles have got much attention because of its physiochemical properties. Gold nanoparticles play a crucial role in the identification of genetic diseases based on biomarkers, SNP genotyping, and detection of nucleic acids in infectious conditions (Singh et al. 2017). Noble metal nanoparticles have been used extensively as tags for nucleic acid probes, and such AuNps can bind to small pieces of DNA of size not larger than 13 nm in diameter. Several FDA-approved products use AuNps as probes for diagnostic purposes (Mieszawska et al. 2013).

1.2.2.2 Quantum Dots (QDs)

Quantum dots (QDs) are inorganic semiconductor nanocrystals with a typical diameter of 2–10 nm. QDs are capable of emitting at very well-defined wavelength upon excitation and have been successfully used for imaging tumor target cells in animal models. Studies have unfolded great relevance of quantum dots in the field of early diagnosis and, also, in the field of locating the cancer tumors in patients and for carrying diagnostic tests in samples (Matea et al. 2017). The recent studies in quantum dots are on its composition of cadmium which is considered to be ounce of toxic, the reason behind the limitations on its use in vivo, and hence, study has been proposed to manufacture quantum dots of silicon as it's considered to be less toxic. Quantum dot is combined with microscopy to look for cells of live animals. The carcinoma marker Her2 is immunofluorescently labeled with the particular cancer antibodies covalently coupled with polyacrylate cap and carbohydrate detectable luminescence is useful for cancer imaging purposes (Zhang et al. 2008a). Another application of QDs is for infectious agent identification. Rapid and sensitive identification of respiratory syncytial virus (RSV) is imperative for the management and development of antiviral. Nanoparticles conjugated with antibody rapidly have been developed which specifically identify RSV (Bawage et al. 2013). When viral particles or infected cells come into the contact with QDs they attach to their surfaces.

1.2.2.3 Magnetic Nanoparticles

The magnetic properties and ease of derivatization of magnetic nanoparticles (MNPs) have been crucial for separation of analytes or to potentiate immobilization prior to recognition step. Detection of trace levels of prostate-specific antigen (PSA) and amyloid-beta derived diffusible ligands (ADDLS) in clinical samples by bio-barcode assay are the prominent applications of MNPs (Cardoso et al. 2018). Within the blood stream, the MNPs attach to form microvesicles that help to identify the target cells. The early diagnosis can be then achieved by using NMR which discovers the microvesicles/magnetic nanoparticle clusters (Zhang et al. 2018b).

1.3 Nanotechnology-Based Therapeutics

1.3.1 Antimicrobial Nanoparticles

One of the encapsulated peptide LL37 has been made to make the nanoparticles with enhanced antimicrobial activity. The combination of LL37 and A1 has been used to develop the first solid lipid nanoparticle (SLN) formulation which can deliver it in precise ratios resulting in enhancing antibacterial activity against *E. coli* and *S. aureus* (Fumakia and Ho 2016). One of the earliest uses of nano-surfaces is nanocrystals which can be utilized as the antimicrobials. Silver ions are released up to 7 days from the surface of nanocrystal and thereby reducing a broad range of microorganisms, including drug-resistant bacteria such as vancomycin-resistant *Enterococcus* and methicillin-resistant *Staphylococcus aureus*. Similarly, zinc oxide nanoparticles, single-wall carbon nanotubes, and antibiotics-coated nanoparticles are also under the major listings for research and study worldwide (Biswaro et al. 2018).

1.3.2 Nanotechnology in Cancer Therapy

The enhancement in carcinogenic treatment depends on the upgraded enhancement and retention (EPR) impact of the vasculature encompassing tumors. For the effective treatment of cancer there is a need to develop targeted drug delivery methods. Tumor focusing with nanoparticles can be acknowledged through active and passive way. The particles can be adjusted with different kinds of materials including biomolecule. The active way depends on binding of ligand-coordinated nanoparticles to receptors expressed by tumor cells (Misra et al. 2010). These ligands include peptides, antibodies, aptamers, nucleic acids, sugars, and tiny molecules. The important factors for the anticancer nanoparticles are the size of the nanoparticles, surface properties (for example hydrophobicity), and focusing on ligands. Nanoparticles intended for tumor focused on treatments comprise of different segments, a nanocarriers and a functioning operator. Nanoparticles carrying drugs are considered as submicroscopic colloidal structure that act as the drug vehicles, either as nanocapsules (repositories in which the drug is kept in hydrophobic or

hydrophilic center encompassed by a single polymeric layer) or nanospheres (framework in which the drug is scattered) (Zhao et al. 2018a). Nanoparticle carriers are typically made out of gold, iron oxides, dendrimers biodegradable polymers, lipid based transporters, for example, liposomes and micelles, viral nanoparticles and organometallic mixes (Zhang et al. 2008b).

1.3.3 Nanoparticles in Antidiabetic Therapy

Diabetes is a kind of chronic disorder which is characterized by high circulating glucose. Several of the ions have been reported to be effective in the maintenance of blood sugar levels such as vanadium, chromium, magnesium, and zinc (DiSanto and Subramanian 2015). Zinc oxide nanoparticles have been shown to be effective via oral administration which shows higher serum insulin (70%), improved glucose tolerance, reduced blood glucose (29%), reduced triglycerides (48%), and reduced nonesterified fatty acids (40%) (Woldu and Lenjisa 2015). Nanoparticles are systemically absorbed resulting in elevated zinc levels in the adipose tissue, liver and pancreas. Amplified secretion of insulin and activity of superoxide dismutase have been observed in rat insulinoma (RIN-5F) cells (Xie and Xie 2018).

1.3.4 Nanoparticles in Regenerative Medicine

Regeneration of damaged tissue or organ has taken a turn with the development of nanotechnology and its application in medicine. The damaged tissue can be repaired and reproduced with the use of nanomedicine. These artificially reproduced cells are then used in tissue engineering revolutionizing the artificial implants and transplantation of organs. In vivo regeneration or, alternatively, in vitro development of a scaffold-based complex functional organ is the aim of regenerative medicine. Various nano-structured materials have been used to regenerate cartilage, bone, muscle, vascular, nervous system, bladder, skin and other tissues in the past few years (Van Rijt and Habibovic 2017). Orthovita's Vitoss is used as bone void filler; a primary example of nano-hydroxyapatite (component of bone) can be used in osseointegration. Mesenchymal stem cells (MSCs) have been shown to be significantly proliferated and differentiated into cardiac cells by AuNp-blended polycaprolactone (PCL) scaffolds which can be used in myocardial infarction repairmen (Jain 2008). Magnetic nanoparticles are used for the isolation and grouping of stem cells, and in addition, carbon nanotubes, fluorescent CNTs, and fluorescent MNPs along with quantum dots have been used for tracing of stem cells, molecular imaging, and gene or drug delivery into stem cells. Stem cells proliferation and differentiation can be regulated by the combination of nanocarriers with biological molecules. Applications of nanotechnology in stem cell biology research are opening the newer path in the area of regenerative medicine (Pan et al. 2017).

1.4 Nanoparticles as Drug Delivery System

Targeted drug delivery can be achieved via nanoparticles mostly due to its high surface area and volume ratio. The specific drug dose is employed, and side effects are considerably reduced since the drug is exclusively deposited within the morbid region. By carrying drugs within, the local drug concentration can be modulated by using nanoparticles and controlling its release upon binding to targets (Patra et al. 2018). Nanoparticles interact with the target cells in variety of ways primarily depending on whether the source materials are non-biological such as gold or cadmium or biological components such as phospholipids. Since the drug needs to be transported and released, the bio-degradable nanoparticle formulations are suitable. Thus various forms of nanoparticles such as nano porous materials and dendrimers have been designed (Castro and Kumar 2013). Micelles which are derived from co-polymers are used for encapsulation of drug. Minute drug molecules can be transported to the specified target sites. The drug consumption as well as the treatment expenses can be reduced to a significant level in the site specific drug delivery, creating the treatment of patients cost effective. With the recent development in nanotechnology, various forms of inorganic nanoparticles have been generated (gold nanoparticles, iron oxide nanoparticles and fullerenes) as an efficient drug carrier or vehicles and few organic nanoparticles (liposomes, micelles) as drug reservoirs (Kumar et al. 2018). Among these liposomes and organic nanoparticles have entered the market, and micelles are yet to be and are still in the clinical trials. Furthermore, polymeric nanoparticles have also gained attention as drug delivery systems (Fig. 1.2).

1.4.1 Impact of Nanoparticles in Drug Delivery System

The present time shows many drugs failing the clinical trial phase because of the poor delivery factor precisely at the targeted site without having an interacting with the nonspecific target sites and organs (Wang et al. 2017). To overcome this problem, NDDS has been majorly studied and, hence, unfolded various remedial options for the efficacy in specific targeting, which is cost-effective and also lowers drug toxicity. Worldwide novel methods are being developed for effective drug delivery methods. NDDS is now expected to be globally accepted which is now making nearly 80% of the drug delivery market. Improvement in human health by tackling the lack of treatment efficacy can be overcome through the utilization of nanoparticles in drug delivery system up to a higher extent comparatively to where it is now (Suri et al. 2007).

1.4.2 Journey of Nanoparticles-Based Delivery

The most consistent route to deliver NDDS (nanoparticle drug delivery system) is usually through intravenous injection although there are various other routes such as pulmonary or oral. Post-injection, the drugs are transported from the injected site

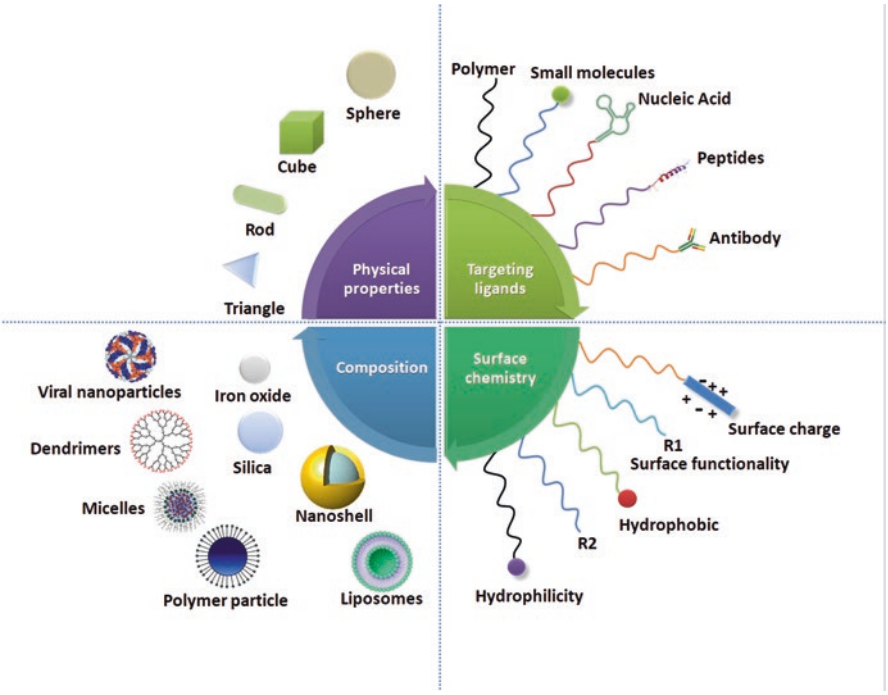

Fig. 1.2 Nanoparticle drug delivery system (NDDS). This figure demonstrates the various forms of nanotechnology-based drug delivery methods. Ligands are of various types such as peptides, antibodies, aptamers, nucleic acids, sugars, and tiny molecules. Targeted drug delivery also can be achieved by considering the size of the nanoparticles, surface properties (e.g., hydrophobicity), and focusing on ligands. Physical properties of nanoparticles are also crucial to determine its binding and absorption to the target site. Nanoparticle carriers are typically made out of gold, iron oxides, dendrimers biodegradable polymers, lipid-based transporters, for example, liposomes and micelles and viral nanoparticles

via the venous network to the heart (Serda et al. 2011). NDDS interacts with proteins present in plasma, and the interaction is monitored by the physiochemical properties of NDDS, and the interactions affect the time of circulation as well as the tissues deposition. The sheathing of NDDS with PEG diminishes the deposition of non-specific protein and complement activation of NDDS.

1.4.3 Nanoparticles-Based Drug Release

Factors to be considered while developing drug delivery system based on nanoparticles are both drug release and polymer degradation. The rate of drug release depends upon various factors such as drug diffusion through the nanoparticles matrix, solubility, desorption of the adsorbed drug, degradation of nanoparticle matrix and the combination of diffusion and degradation process (Rizvi and Saleh

2018). The particle release regulates solubility, diffusion and biodegradation of the drug. For nanoparticles, the release of drugs is displayed by erosion or matrix spread. In case of polymer-coated nanoparticles, the release from the polymeric membrane is controlled by the diffusion of the drug, and the covering of the membrane is used to prevent drug release. Hence, the diffusion and solubility of drug in or across the membrane are considered to be the determining factors for drug release (Okada and Toguchi 1995). The foremost objective of delivery systems is to release their payload at the target site. To accomplish this objective, the key approaches are active and passive targeting. Nanoparticles-based drug delivery is a passive approach as the drugs encapsulate in nanoparticles and drugs linked with macromolecules can target tumors passively due to improved permeability with retention effect. Liposomes are further useful for delivering pharmaceuticals agents (Yu et al. 2016).

1.4.4 Liposomes

Liposomes demonstrated possibility for conveyance of a wide scope of therapeutics, since their payload can be encapsulated in their interior fluid compartment or inserted inside the phospholipid bilayer (Jain 2008; Akbarzadeh et al. 2013). Clinical utilizations of liposomes in the conveyance of anticancer specialists for the treatment of various malignant growth signs are entrenched. Stealth liposomes can inactively collect in strong tumors due to their inalienably broken vasculature and faulty lymphatic seepage. Doxil, Caelyx, and Myocet are nano-meter-sized liposome frameworks (exemplifying doxorubicin in their fluid center) which have been utilized for Kaposi's sarcoma, ovarian disease, and various myelomas (Cattel et al. 2003). DepoCyt (cytarabine-containing multivesicular liposomes) with a sustained-discharge profile has likewise been endorsed for malignancy treatment. Reported treatment is done by the use of Cremophor EL in case of head and neck cancer that allows the paclitaxel to be delivered intravenously. Carbon nanoparticles have been replaced at the place of toxic Cremophor, use less paclitaxel, and show reduced side effects along with improved drug targeting. Similarly, an albumin-bound paclitaxel, namely, Abraxane has been studied in case of the breast cancer and non-small cell lung cancer (Olusanya et al. 2018). In addition, doxorubicin has been delivered by using a bound nanoparticle chain in case of breast cancer cells. Within the tumor post-penetration of the nano chains was performed with the help of magnetic nanoparticles (Zhao et al. 2018b). Tumor growth has been shown to be halted significantly by nanotechnology than the conventional treatment and is less harmful to healthy cells.

1.4.5 Hybrid Nanoparticles in Drug Delivery System

To control a targeted delivery, some of the nanoparticles are manipulated by the external magnetic field gradient, and such nanoparticles are termed as hybrid nanoparticles that are reported to be highly efficient in drug delivery system. Such

magnetite-polymer hybrid nanoparticles can be attached to fluorescence groups; these hybrid nanoparticles are proficient tracers of drug transporters due to the enrichment of fluorescence molecules. This allows the magnetic nanoparticles to be more widely applied in site specific drug delivery system (Madni et al. 2017). Multicomponent hybrid nanoparticles may possess multiple functionalities for various applications that are complicated to attain with nanoparticles of single component. Noble metal/iron oxide hybrid nanoparticles not only show unique optical properties but also exhibit magnetic resonance. Hybrid nanoparticles can be of great help in drug delivery system especially in cases of cancer and, precisely, in the treatment of multidrug-resistant cancer (Date et al. 2018).

1.5 Conclusions

Considering the various biological, pharmaceutical molecules and structures that operate in the living cells, the size scale is of 100 nanometers and less, and hence, the application of nanotechnology in healthcare presents some stimulating potential outcomes. Prescription nanotechnology may change the way we detect and treat human body and illness damage in the future, and several procedures that have just been planned a few years earlier are becoming a marvelous ground for substances. Nanotechnology is a useful asset for making these "smart" materials. This methodology is challenging and is still a long way from being accomplished. Nanoplatforms have been seen to be taking lead in the development of targeted nanomedicine for anticancer therapy in the upcoming time. Detection, prevention and treatment of various forms of cancers are possible using such nanoplatform techniques based targeted anticancer therapy without toxicity and with enhanced biocompatibility of nanoplatform. Diabetics can become totally free of dietary regulations and the strict systemic regime if nanotechnology is at the forefront. Some devices are so adjustable that people with diabetes are no longer dependent on insulin injections, and at this moment their blood glucose concentrations are adjusted to their glucose levels. This would allow them to live a normal life, particularly young people who are always active. It helps the patient to feel more confident and mentally safe as well as cost-effective in other respects, because fewer resources are required to achieve a significantly more effective result.

1.6 Future Perspectives

One of the most crucial factors which have led to the designing and advancement of various nano-based drugs is the small size that enables the successful delivery of the drugs in the specific site. A significant advancement in the area of nanotechnology-based drug delivery has been achieved with the remaining question of associated toxicity on human body. The impact of nanoparticles on biological systems depends on the size, chemical nature and composition, solubility, shape, surface structure, and aggregation. These factors can modulate the cellular uptake, translocation from

entry to the target sites, target affinity and possibility of causing injury to tissues. Pharmacodynamics of nanoparticles depends upon the route of exposure such as skins, GI tract, systemic administration for diagnosis and therapeutic applications. Personalized medicine can be developed based on nanotechnology by several means. Nanotechnology-based diagnostics may improve the present restrictions of detection limits as well as enhances the molecular imaging. Nanotechnology can be integrated in detection of biomarkers, biochips, point of care diagnosis and biosensors which are crucial for developing personalized nanomedicine. Ethical consideration is crucial for all nanotechnology-based applications in medicine. Nanotechnology has not raised new ethical issues so far; it is advisable to keep the associated ethical considerations while developing and applying nano based therapeutics. Moreover, there is a need to develop unique ethical questionnaire distinct from conventional form of medicines.

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References

Akbarzadeh A, Rezaei-Sadabady R, Davaran S, Joo SW, Zarghami N, Hanifehpour Y, Samiei M, Kouhi M, Nejati-Koshki K (2013) Liposome: classification, preparation, and applications. Nanoscale Res Lett 8(1):102

Archakov AI (2010) Nanobiotechnologies in medicine: nanodiagnostics and nanodrugs. Biomed Khim 56(1):7–25

Baptista PV (2014) Nanodiagnostics: leaving the research lab to enter the clinics? Diagnosis (Berl) 4:305–309

Bawage SS, Tiwari PM, Pillai S, Dennis V, Singh SR (2013) Recent advances in diagnosis, prevention, and treatment of human respiratory syncytial virus. Adv Virol 2013:595768

Bayford R, Rademacher T, Roitt I, Wang SX (2017) Emerging applications of nanotechnology for diagnosis and therapy of disease: a review. Physiol Meas 38(8):R183–R203

Biswaro LS, da Costa Sousa MG, Rezende TMB, Dias SC, Franco OL (2018) Antimicrobial peptides and nanotechnology, recent advances and challenges. Front Microbiol 9:855

Cardoso VF, Francesko A, Ribeiro C, Bañobre-López M, Martins P, Lanceros-Mendez S (2018) Advances in magnetic nanoparticles for biomedical applications. Adv Healthc Mater 7(5): 1–35, 1700845

Castro E, Kumar A (2013) Nanoparticles in drug delivery systems. In: Nanomedicine in drug delivery. pp 1–22

Cattel L, Ceruti M, Dosio F (2003) From conventional to stealth liposomes: a new frontier in cancer chemotherapy. Tumori 89(3):237–249

Cole LE, Ross RD, Tilley JM, Vargo-Gogola T, Roeder RK (2015) Gold nanoparticles as contrast agents in x-ray imaging and computed tomography. Nanomedicine (Lond) 10(2):321–341

Date T, Nimbalkar V, Kamat J, Mittal A, Mahato RI, Chitkara D (2018) Lipid-polymer hybrid nanocarriers for delivering cancer therapeutics. J Control Release 271:60–73

DiSanto RM, Subramanian V, Gu Z (2015). Recent advances in nanotechnology for diabetes treatment. Wiley Interdiscip Rev Nanomed Nanobiotechnol. 7(4): 548–564

Emeto TI, Alele FO, Smith AM, Smith FM, Dougan T, Golledge J (2017) Use of nanoparticles as contrast agents for the functional and molecular imaging of Abdominal Aortic Aneurysm. Front Cardiovasc Med 4:16
Fumakia M, Ho EA (2016) Nanoparticles encapsulated with LL37 and Serpin A1 promotes wound healing and synergistically enhances antibacterial activity. Mol Pharm 13(7):2318–2331
Goldman LW (2007) Principles of CT and CT technology. J Nucl Med Technol 35(3):115–128
Jain KK (2008) Nanomedicine: application of nanobiotechnology in medical practice. Med Princ Pract 17(2):89–101
Jones T, Townsend D (2017) History and future technical innovation in positron emission tomography. J Med Imaging (Bellingham) 4(1):011013
Kim D, Kim J, Park YI, Lee N, Hyeon T (2018) Recent development of inorganic nanoparticles for biomedical imaging. ACS Cent Sci 4(3):324–336
Kumar S, Maurya VK, Dandu HR, Bhatt ML, Saxena SK (2018) Global perspective of novel therapeutic strategies for the management of NeuroAIDS. Biomol Concepts 9(1):33–42
Logothetidis S (2006) Nanotechnology in medicine: the medicine of tomorrow and nanomedicine. Hippokratia 10(1):7–21
Madni A, Tahir N, Rehman M, Raza A, Mahmood MA, Khan MI, Kashif PM (2017) Hybrid Nano-carriers for potential drug delivery. Adv Technol Deliv Ther (Book): 53–87. https://doi.org/10.5772/66466. IntechOpen
Matea CT, Mocan T, Tabaran F, Pop T, Mosteanu O, Puia C, Iancu C, Mocan L (2017) Quantum dots in imaging, drug delivery and sensor applications. Int J Nanomed 12:5421–5431
Mieszawska AJ, Mulder WJ, Fayad ZA, Cormode DP (2013) Multifunctional gold nanoparticles for diagnosis and therapy of disease. Mol Pharm 10(3):831–847
Miller AD (2016) Nanomedicine therapeutics and diagnostics are the goal. Ther Deliv 7(7):431–456
Misra R, Acharya S, Sahoo SK (2010) Cancer nanotechnology: application of nanotechnology in cancer therapy. Drug Discov Today 15(19–20):842–850
Naseri N, Ajorlou E, Asghari F, Pilehvar-Soltanahmadi Y (2018) An update on nanoparticle-based contrast agents in medical imaging. Artif Cells Nanomed Biotechnol 46(6):1111–1121
Okada H, Toguchi H (1995) Critical reviews in therapeutic drug carrier systems. Crit Rev Ther Drug Carr Syst 12(1):1–99
Olusanya T, Haj Ahmad R, Ibegbu D, Smith J, Elkordy A (2018) Liposomal drug delivery systems and anticancer drugs. Molecules 23(4):907
Pan S, Yu H, Yang X, Yang X, Wang Y, Liu Q, Jin L, Yang Y (2017) Application of nanomaterials in stem cell regenerative medicine of orthopedic surgery. J Nanomater 2017:1–12, 1985942
Patra JK, Das G, Fraceto LF, Campos EVR, Rodriguez-Torres MDP, Acosta-Torres LS, Diaz-Torres LA, Grillo R, Swamy MK, Sharma S, Habtemariam S, Shin HS (2018) Nanobased drug delivery systems: recent developments and future prospects. J Nanobiotechnol 16(1):71
Rizvi SA, Saleh AM (2018) Applications of nanoparticle systems in drug delivery technology. Saudi Pharm J 26(1):64–70
Rizzo LY, Theek B, Storm G, Kiessling F, Lammers T (2013) Recent progress in nanomedicine: therapeutic, diagnostic and theranostic applications. Curr Opin Biotechnol 24(6):1159–1166
Sands MJ, Levitin A (2004) Basics of magnetic resonance imaging. Semin Vasc Surg 17(2):66–82
Saxena SK, Tiwari S, Nair MP (2012) Nanotherapeutics: emerging competent technology in neuroAIDS and CNS drug delivery. Nanomedicine (Lond) 7(7):941–944
Serda RE, Godin B, Blanco E, Chiappini C, Ferrari M (2011) Multi-stage delivery nano-particle systems for therapeutic applications. Biochim Biophys Acta 1810(3):317–329
Silindir M, Özer AY, Erdoğan S (2012) The use and importance of liposomes in positron emission tomography. Drug Deliv 19(1):68–80
Singh L, Kruger HG, Maguire GEM, Govender T, Parboosing R (2017) The role of nanotechnology in the treatment of viral infections. Ther Adv Infect Dis 4(4):105–131
Suri SS, Fenniri H, Singh B (2007) Nanotechnology-based drug delivery systems. J Occup Med Toxicol 2(1):16

Tognarelli JM, Dawood M, Shariff MI, Grover VP, Crossey MM, Cox IJ, Taylor-Robinson SD, McPhail MJ (2015) Magnetic resonance spectroscopy: principles and techniques: lessons for clinicians. J Clin Exp Hepatol 5(4):320–328

Van Rijt S, Habibovic P (2017) Enhancing regenerative approaches with nanoparticles. J R Soc Interface 14(129). pii: 20170093

Wang YF, Liu L, Xue X, Liang XJ (2017) Nanoparticle-based drug delivery systems: what can they really do in vivo? F1000Res 6:681

Woldu MA, Lenjisa JL (2015) Nanoparticles and the new era in diabetes management. Int J Basic Clin Pharmacol 2014(3):277–284

Xie F, Xie L (2018) Serum zinc level is associated with liver dysfunction caused by white smoke inhalation. Gastroenterol Rep 6(4):304–307

Yu X, Trase I, Ren M, Duval K, Guo X, Chen Z (2016) Design of Nanoparticle-Based Carriers for targeted drug delivery. J Nanomater. pii: 1087250

Zhang H, Yee D, Wang C (2008a) Quantum dots for cancer diagnosis and therapy: biological and clinical perspectives. Nanomedicine (Lond) 3(1):83–91

Zhang L, Gu FX, Chan JM, Wang AZ, Langer RS, Farokhzad OC (2008b) Nanoparticles in medicine: therapeutic applications and developments. Clin Pharmacol Ther 83(5):761–769

Zhang W, Wang W, Yu DX, Xiao Z, He Z (2018a) Application of nanodiagnostics and nanotherapy to CNS diseases. Nanomedicine (Lond) 13(18):2341–2371

Zhang H, Liu XL, Zhang YF, Gao F, Li GL, He Y, Peng ML, Fan HM (2018b) Magnetic nanoparticles based cancer therapy: current status and applications. Sci China Life Sci 61(4):400–414

Zhao CY, Cheng R, Yang Z, Tian ZM (2018a) Nanotechnology for Cancer Therapy Based on Chemotherapy. Molecules 23(4). pii: E826

Zhao N, Woodle MC, Mixson AJ (2018b) Advances in delivery systems for doxorubicin. J Nanomed Nanotechnol 9(5). pii: 519

Zitka O, Ryvolova M, Hubalek J, Eckschlager T, Adam V, Kizek R (2012) From amino acids to proteins as targets for metal-based drugs. Curr Drug Metab 13(3):306–320