Applications of Nanotechnology in Drug Delivery

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Abstract

Nanotechnology encompasses development of drug delivery system at atomic and molecular level. It is combination of tools and ideas which are adopted by pharmaceutical industries for novel and site specific based drug delivery. Based on nanotechnology, various biomaterials and devices are designed with high specificity and selectivity to interact with cellular and receptor levels which are achieved by regulating the shape and size of particle at nanometer size. These nanoparticles are having huge applications in drug delivery for various diseased conditions such as cancer, cardiovascular, infectious diseases like Malaria, HIV and so on. Nanotechnology has also become an effective method for delivering cosmeceutical showing promising results. Nanotechnology has even revolutionized personalized medicine sector. In the present paper, an attempt has been made to outline applications of nanotechnology in various sectors.

Keywords: *Nanotechnology, Cancer, Infectious Diseases, Cosmeceuticals, Preclinical and Clinical Studies*

1. INTRODUCTION

Delivering active compound to the target site is a key issue in addressing treatment for many diseases. Due to various limitations exhibited by conventional delivery of drug such as poor bioavailability and bio-distribution, lack of selectivity, systemic toxicity etc., novel technologies have been implemented in delivering drug to target site. Nanotechnology is one of the most promising and emergering tool in pharmaceutical drug delivery systems to overcome conventional drug delivery drawbacks[1,2,3]. The application of nanotechnology in health care sector has attained greater importantance in recent times. Nanoparticles have ability to transport hydrophobic drug bypassing hepatic metabolism thereby enhancing its peroral bioavailability, prolonged effect with favorable bio-distribution and pharmacokinetic profiles. These technologies are designed to achieve sustained and persistent drug release with lesser variations in plasma concentration and diminishing possible side-effects. These technologies protect encapsulated drug from degradation and deliver them at the site of action. This review emphasizes on the various applications of nanotechnology in drug delivery [3,4].

2. ADVANTAGES OF NANO-SIZED PARTICLES

Nano-sized particles have numerous advantages such as [3, 4]

- Nanomaterials can be conjugated with biomolecules to enable target specific delivery of drug
- Nanopartices are similar to biomolecules such as receptor in size and hence they can easily bind with them
- Nanostructures are used in bioimaging due to their optical properties
- Nanosize contributes to site specific targeting is easier resulting in minimal side effects
- These formulations often releases therapeutic payloads (agents) to cancer sites and significantly reducing nonspecific toxicity

3. APPLICATION OF NANO - TECHNOLOGY IN BIO-PHARMACEUTICALS

Nanomaterials have significance applications in biopharmaceutical field due to [4,5,6]

- Reduced particle size, increased surface area, better solubility and bioavailability characteristics

- Site specific targeting of tissues, cells and receptors
- Delivery of vaccine and gene with improved shelf life
- Ease in delivery of large macromolecule drugs to intracellular sites of action
- Simultaneous delivery of two or more drugs used in combination therapy
- Can easily target the blood brain barrier
- Formulations are designed to release drug in controlled manner
- Estimation of *in-vivo* efficacy of a therapeutic agent
- Improved biocompatibility due to development of artificial surface engineering of implants

4. APPLICATION OF NANO-TECHNOLOGY IN VARIOUS DISEASES

4.1 Nanotechnology Based Drug Delivery in Cancer[5,6]

- Newer approaches for the treatment of cancer have been developed using nanotechnology. Nanotechnology is renovating the conventional therapies concept with early diagnosis, treatment and emphasizing on prevention. Brain tumors are most difficult to diagnose and treat whereas nanoparticles are been proven to hold promising delivery of drugs across the blood–brain barrier
- Nanoparticles coated with a ligand, antibody or an aptamer are developed to bind on tumor cell-surface receptor in order to achieve specific internalization and subsequent accumulation of drugs within the targeted tumor cell
- Predictive modeling of accumulation and distribution patterns using computer simulations provides highly effective analyses regarding drug and its effectiveness. These modeling are then correlated with *in-vivo* distribution and efficacy studies. To improve translational potential, animal models that imitating cancer conditions in humans in terms of affected organ, vasculature, reactivity and metastatic advancement should be considered in the selection and designing protocol

4.2 Nanotechnology based Drug Delivery in Infectious Diseases [7,8]

- Treatment for infectious diseases has become quite challenging even with various broad spectrum antibiotics availability. This is because of resistance developed by pathogens for existing drugs
- These diseases are more seen in developing and underdeveloped countries especially in pediatric population. Nanotechnology based drug delivery especially vaccines containing nano-particles has changed the view about infectious diseases such as HIV, Tuberculosis and malaria. Nanoparticulates can also enhance the immuno-stimulatory properties of conventional vaccines

4.2.1 HIV/AIDS[9]

- Numerous nanoparticles are designed by conjugating a nanomaterial with a biologically derived or biologically based component such as a nucleic acid, protein, peptide or antibody. *In vitro* experiments demonstrated that the multifunctional bioconjugates had significantly different cellular uptake and anti-HIV potency compared to the prodrug alone
- As the disease is commonly seen in both the adult and the pediatric population, development of anti-HIV nanomedicines could be beneficial for wide population. Despite of the strategy of choice, the manufacturing process should be economical in order to ascertain patient affordability

4.2.2 Tuberculosis [8,10]

- Novel technologies are applied to develop formulations to facilitate pediatric sector. Attempts have been made to develop effective polymeric lipid nanoparticles for TB. Based on studies, nanomedicnes have proven to be promising replacement of conventional therapy and also facilitate the

implementation of a Directly Observed Treatment, Short Course (DOTS) therapy

- Nanobead delivery has a characteristic slow, sustained and controlled release of drug from a biodegradable particle. Different animal models have been studies in order to develop an antibiotic therapy based on polymer technology against M. tuberculosis

4.2.3 Malaria[11]

- Malaria being infection caused by parasities are having higher morbidity and mortality rate. The first-line therapy for malaria is artemisinin combined therapies (ACTs) available in tablets form. As the tablets are difficult to be swallowed, WHO has called for the development of novel oral ACT formulation for pediatric sector. Formulating suspensions, dispersible tablets and granules containing artemether and its combination has been of significant importance
- Several compounds such as lipids, proteins, nucleic acid and metallic nanoparticles (NPs) have been successfully used for the control of this lethal malaria disease
- Other useful natural reagents such as carbohydrates, vitamins, plant extracts are also used in management of malaria. The plant-based particles such as leaf, root, stem, latex, and seed are showing the best antagonistic response against malaria. Various studies are concluding that for a better solution, nanobiotechnology principle has to be implemented for both vector control and patient therapy

4.3 Nanotechnology based Drug Delivery in Cardiovascular Disease[10,11,15]

- Nanotechnology may provide an effective treatment of disease with minimal side effect. Development of polymer based nanoparticles targeting inflamed tissue and modified to release drugs in the presence of hydrogen peroxide that generally found in those inflamed tissues are taken significant place in cardiovascular drug therapy
- Preclinical studies in mice have shown that nanoparticles aid in targeting tissue plasminogen activator (tPA) to blood clot without side effects and internal bleeding. Magnetic nanoparticles for delivering drug to stents are also being developed

4.4 Nanotechnology based Drug Delivery in Cosmeceuticals[16,17,18]

- Cosmeceuticals are considered as the faster emerging section of the personal care and health care industries
- Nano-cosmeceuticals are used extensively for skin, hair, nail and lip care related conditions such as wrinkles, photoaging, hyper-pigmentation, dandruff and hair damage
- Nanomaterials are widely used in the preparation of antiwrinkle creams, moisturizing creams, skin whitening creams, hair repairing shampoos, conditioners and hair serums
- Liposomes, niosomes, nanoemulsions, microemulsion, solid lipid nanoparticles, nanostructured lipid carrier and nanospheres have replaced the conventional delivery system
- Inclusion of nanocarriers in bulk manufacturing of skin care, lip care, hair care and nail care products have been increased due to their long lasting effect
- Novel nanocarriers have significant advantages like improved skin penetration, controlled or sustained or prolong release of drug, better stability, site specifc targeting and high entrapment efficiency

4.4 Nanotechnology based Drug Delivery in other Areas[19,20,21]

- Contact lenses containing nano-diamonds are developed for glaucoma treatment where the drug is released when the nano-diamonds are in contact with tears giving precise dose than eye drops
- Dental implants attached with nanotubes are gaining more importance in dentistry
- Nanoparticles including both insulin and an enzyme are developed for diabetic condition. Here the enzyme gets dissolved in

presence of high glucose triggering insulin release in the blood stream

- Similarly, nanocapsule containing an enzyme and sponge like matrix containing insulin are developed which dissolves in presence of high glucose and initiates insulin release from sponge
- Nanoparticles have even revolutionized in the field of autoimmune diseases by delivering antigens for a particular disease into the blood stream

4.5 Nanotechnology based Drug Delivery in Personalized Medicine[20,21,23]

- Based on individual patient, their genetic and environmental factors, prescriptions are developed for their specific conditions are known as personalized medicines. For attaining success in therapy, highly specific and sensitive diagnostic tool with safe and effective therapeutic agents have to be developed
- Nanobiotechnology has significantly contributed in this area with help of innovative technologies that have refined methods for disease diagnosis and platforms for site specific drug release. Impact of nanotechnologies in drug development is also emerging as a promising way to achieve success in personalized medicines

4.6 Nanotechnology in Preclinical and Clinical Drug Development (6,24)

- Nanotechnology is generating a strong impact in preclinical and clinical drug development. Preclinical studies helps in better understanding of relationship between cellular mechanisms and new potential drugs or improved formulations of existing drugs
- The diversity of current nanotechnologies offers a broad platform used to enhance the performance of drug discovery screening, to develop sensitive and specific methods used to reveal the mechanisms behind the actions of drugs, to determine the function and interaction between molecules and to understand the physiological and pathological changes of cellular components for particular disease

5. CONCLUSION

Nanomedicine or nanotechnology promises to be main source for drug development and its effective delivery in various diseased conditions. These novel technologies have transformed the path of treatments due to their derived distinctive physicochemical and biological characteristics owing to site specific delivery and with very minimal side effects. Because of their significantly improved skin penetration, controlled or sustained delivery of drug, this technology has improved cosmeceutical delivery to greater extent.

Nanotechnology enables us to design and deliver the drug for individual patient based on their specific requirement i.e., personalized medicine with maximum benefits aiding in faster recovery from aliments. Nanotechology based drug delivery due to their advanced characteristics enables wide range of new and special applications in pharmaceutical field.

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