The Pharma Innovation Journal 2023; 12(11): 67-70

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 67-70

www.thepharmajournal.com
Received: 27-09-2023
Accepted: 30-10-2023

Vimal Kishore
Dr. A.P.J. Abdul Kalam University, Indore, Madhya Pradesh, India

Sunena
School of Pharmaceutical Sciences, Om Sterling Global University, Hisar, Haryana, India

Pawan Jalwal
Faculty of Pharmaceutical Sciences, Baba Mastnath University, Rohtak, Haryana, India

Corresponding Author:
Vimal Kishore
Dr. A.P.J. Abdul Kalam University, Indore, Madhya Pradesh, India

Recent advancements in nanoparticles based drug delivery

Vimal Kishore, Sunena and Pawan Jalwal

DOI: https://doi.org/10.22271/tpi.2023.v12.i11a.24365

Abstract
Materials in the nanoscale range are used as diagnostic tools or to deliver therapeutic agents to specific targeted sites in a controlled manner in the relatively new field of nanomedicine and nano delivery systems. Through the site-specific and target-oriented delivery of precise medications, nanotechnology offers numerous advantages in the treatment of chronic human diseases. Chemotherapeutic agents, biological agents, immunotherapeutic agents, and other exceptional uses of nanomedicine have been observed recently in the treatment of a wide range of illnesses. This review provides an updated overview of recent developments in the field of nano-based drug delivery.

Keywords: Nanomedicine, drug delivery, site specific, therapeutics, nanotechnology

1. Introduction
The term "nano" comes from ancient Greek and means "dwarf". Nanoparticles are the particles having nano scale dimensions lies in range between 1 nm to 100 nm and can exhibit significantly different physical and chemical properties to their larger material counterparts. It is observed that the therapeutic efficacy of most the drug delivery systems is highly depends on its particle size. Owing to their very small size, nanoparticles have large surface area to volume ratio when compared to their bulk material, such as powders, plate and sheet. This feature enables nanoparticles to possess unexpected optical, physical and chemical properties. The medical field, for example, utilizes nanomaterials in a variety of ways, with one major use being drug delivery [1]. Nanoparticles are widely used as drug delivery tool to provide enhanced solubility, better bioavailability, pronounced systemic stability, high drug loading capacity, significant blood circulation time and selective distribution in tissues with longer residence time [2]. Nanoparticles can enter cells or to be designed to bind to specific cells and this unique property is highly utilized for the tumor cell targeting or site specific targeting against many diseases [3]. Nanoparticles exhibits small size and large surface area due to which their solubility gets enhanced and imparts higher bioavailability. Drug loaded nanoparticles able to cross the blood brain barrier and other epithelial barriers such as nasal olfactory epithelium and skin [4]. The most significant application of nanoparticles is that they can cross the BBB due to their small size and used for drug targeting to the brain [6]. Nanoparticles having size smaller than 20 nm can transport paracellularly to cross the BBB and reach the brain.

Size and shape of the nanoparticles greatly affect its pharmacokinetics inside the body. The tissue distribution of the drug mainly depends upon its size. Smaller the size of nanoparticles higher will be the tissue uptake [5]. Due to small size, the nanoparticles surface area is comparatively high and thus improved solubility and faster drug release. Overall the size of nanoparticles will decide the pharmacological fate. Major obstacle encountered in nanoparticle mediated drug delivery is clearance by the reticuloendothelial system (RES). It is found that lymphatic system remove the particles size greater than 200 nm by its activation [7]. In short, size and morphological properties of nanoparticles have been investigated to control bioavailability, decrease clearance, prolong systemic circulation and improve stability for better therapeutic effect.

1.1 Advantages of nanoparticles in drug delivery
1.1.1 Advantages of nanoparticles in drug delivery are summarized here
- Enhancement of solubility of poorly water soluble drugs.
- Improved Bioavailability and pharmacological activity.

- Better drug tissue distribution and deposition.
- Provide controlled and targeted drug delivery.
- Protection of drug from physical and chemical degradation.
- Enhancement of formulation stability inside different biological environment.
- Less toxicity and fewer side effects.

1.2 Different Types Nanoparticles Used In Drug Delivery

1.2.1 Liposomes

Liposomes are spherical shaped nano range vesicles made up of outer phospholipid bilayer membrane with an inner aqueous core [8]. They can be used for the entrapment of hydrophilic and hydrophobic both types of drug molecules. Hydrophobic drugs are loaded in to lipid bilayer whereas hydrophilic drugs can be loaded in to the aqueous core [9]. Liposomes are also well compatible for the delivery of various macromolecules such as DNA, proteins, nutraceuticals and diagnostic or imaging agents [10]. Liposomal drug delivery systems show many advantages such as controlled and targeted drug delivery, biocompatible and biodegradable [11]. The liposomal systems are designed and characterized by various features such as particle size, shape, charge, type of lipid, and surface binding polymers and ligands [10]. Overall liposomes offer a versatile and adaptable drug delivery tool for enhancing the systemic efficacy and site specific targeting of therapeutics in various disorders. Liposomes are used as drug delivery carriers for tumor and brain targeting as well as for topical applications.

1.2.2 Inorganic nanoparticles

These types of nanoparticles are made of metal and non - metal substances with varied material properties and thus have many potential medical applications [11]. The most commonly used metal nanomaterials are gold and silver metals. The metal nanomaterials are shaped in to different types of drug delivery systems such as nanotubes, nanorods, nano-capsules and nanowires etc. The gold nanoparticles are widely employed in tumor targeting and also in the treatment of rheumatoid arthritis [13]. Silver nanoparticles mainly involved in antibacterial, anti-infection and anti-tumor effects Inorganic non-metallic nanomaterials mainly include quantum dots, iron oxide, silicon, graphe ne. The non-metallic nanoparticles mainly employed in diagnostic and imaging applications [14]. Silicon mesoporous nanoparticles are widely explored in drug delivery applications [15]. In the cosmetics industry, titanium oxide nanoparticles are used in sunscreen to provide UV protection. The major obstacle behind their restricted use in clinical application is their toxicity problem [16].

1.2.3 Polymeric nanoparticles

Polymeric nanoparticles are prepared from various types of natural, semi-synthetic and synthetic polymers. The most commonly used natural polymers are chitosan, sodium alginate, gelatin, albumin etc. and synthetic polymers such as polylactide–polyglycolide copolymers, polyacrylates and polycaprolactones (PCL), polylactic acid (PLA), poly (lactic-co-glycolic acid) (PLGA) are used for the preparation of the polymeric nanoparticles [17, 18]. The potential advantages of natural polymers are biocompatibility and biodegradable [19]. The most widely used synthetic polymers are PLA and PLGA due to their high tissue compatibility and thus employed in controlled drug delivery systems for parenteral and implants. The polymeric nanoparticles show good stability, high drug loading and poor leakage of drug from polymer shell. The stable structure of polymer nanoparticles is beneficial to the uniformity of particle size and the controlled release of drugs. Polymeric micelles are nanosized, spherical colloidal particles with hydrophobic interior core and hydrophilic exterior shell [20]. They are used for the solubility enhancement of poorly water soluble drugs such as amphotericin B, propofol, paclitaxel, and photosensitizers.

Different types of polymer used for the fabrication of nanoparticles

(A) Natural Polymers

- Chitosan
- Gelatin
- Sodium Alginate
- Albumin

(B) Synthetic Polymers

- Polylactide (PLA)
- Poly(lactide co - glycolide) PLGA
- Poly (ε-caprolactone) PCL
- Poly acrylates & Polymethacrylates (Eudragit)
- Poly lactide- poly(ethylene glycol) PLA -PEG
- Poly(lactide- co - glycolide) - poly(ethylene glycol) PLGA -PEG
- Poly (ε-caprolactone) - poly(ethylene glycol) PCL -PEG

1.2.4 Solid lipid nanoparticles

Solid lipid nanoparticles (SLNs) are lipid based submicron colloidal carriers and found solid at room temperature. They are used as alternative drug delivery systems over the conventional systems such as emulsions, liposomes, polymeric microparticles or microcapsules etc. The major advantage of the wider use of solid lipid nanoparticles is their high physical stability, protection of labile drug encapsulated, controlled release and excellent tolerability. SLNs are versatile drug delivery systems and can be given by various routes like parenteral, oral, dermal, ocular, pulmonary and rectal etc. [21]. The highly lipophllic nature of SLNs make them capable to cross the blood brain barrier and thus effectively used in brain targeting of many drugs such as doxitaxel, paclitaxel and camptothecin etc and otherwise they cannot cross the BBB. Surface modified or ligand conjugated SLNs are used for the brain targeting of many CNS acting drugs [22]. SLNs are also widely used in tropical drug delivery, follicular drug delivery and epidermal drug targeting by providing extra skin hydration effect due to occlusivity. Tropical drug delivery for the treatment of psoriasis is highly recommended in form of solid lipid nanoparticles [23].

1.2.5 Dendrimers

Dendrimers are synthetic, well-defined and highly branched, mono-dispersed symmetric molecular carriers. They can exhibit superior physicochemical and rheological properties as compared to conventional linear polymers. Regardless of the advancements in dendrimer research, the use of dendrimers as drug carriers is still slightly converted into the clinical application [24]. The major potential use of dendrimes is limited to anticancer therapy [25]. The major toxicity issues related to the restricted use are their cytotoxic and hemolytic effects on cells and tissues [26].

1.2.6 Quantum dots
Quantum dots are heterogeneous, semiconductor nano-crystals structures ranging from 2 to 10 nm in diameter size. QDs are prepared from semiconductor materials via colloidal synthesis or electrochemistry in to colloidal nano-crystals of different shapes. They provide adequate surface area to attach therapeutic agents for simultaneous drug delivery and *in vivo* imaging in cancer treatment. QDs are used for drug loading, targeting, controlled release, and monitoring of pharmacokinetics and biodistribution [27]. Further advancement, fluorescent carbon quantum dots (CQDs) have developed with the potential applications in sensing, imaging and drug delivery applications [28].

1.2.7 Fullerenes
Fullerenes, a carbon allotrope also called as "bulky balls". They are being investigated for drug transport of antiviral drugs, antibiotics and anticancer agents [29, 30].

1.2.8 Nanotubes
Carbon nanotubes are tubular structures like a sheet of graphite rolled into a cylinder capped at one or both ends by a buckyball. Nanotubes are used as drug delivery tool in gene therapy [30]. Carbon nanotubes are also being developed in order to be used in processes such as the addition of antibodies to the nanotubes to create bacteria sensors [31, 32].

1.3 Mucoadhesive Nanoparticles
Mucoadhesive novel drug delivery systems have been extensively evolved in recent years due their important role in drug targeting. In various studies, the potential of various novel delivery systems such as liposomes, niosomes, inclusion complexes, microspheres, polymeric nanoparticles, solid lipid nanoparticles, nanostructure lipid particles, etc. in resolving the problem associated with topical delivery of drugs has been widely explored [33]. Nanoparticle based drug delivery systems represent a stable new advanced approach with minimum side effects, therapeutically effective and have excellent potential for site-specific targeted drug delivery [34].
Among various innovative drug delivery technologies, mucoadhesive nanoparticles has been extensively used in current research work due to their dual application as limiting the clearance by increasing the viscosity of a drug formulation and also by increasing the contact time through mucoadhesive linkage between the dosage form and mucosa will result in an enhanced bioavailability at the target site [35]. Mucoadhesive polymers are favorable agents for the design and development of controlled drug delivery systems at the target site. The topical delivery of drugs absorbed through the skin or mucosal lining directly get in to the blood circulation and thus it by-pass first pass metabolism and also keep away from enzymatic degradation in the gastrointestinal track and overall increases the bioavailability and minimizes the side effects of the drugs [36]. The mucoadhesive phenomenon of the polymers or mechanism of mucoadhesion is generally based on the different chemical interactions such as hydrogen bonding and ionic linkages between the mucoadhesive polymer and biological membranes or mucosal tissues.
In the design and formulation of novel topical dosage forms, various type of drug delivery tools are utilized for the improvement in the bioavailability of poorly water soluble drugs that are otherwise less affective after topical administration. Many studies have reported that are supporting the use of nanoparticles for a wide range of benefits including topical delivery of the various drugs. Nanoparticles have some unique physicochemical properties due their nanosize such as increase in water solubility and absorption of drugs through biological membranes. Mucoadhesive nanoparticles offer the many advantages over the conventional drug delivery systems such as proper attachment or binding with the mucosa increase the retention of the dosage form at the target site, improves drug penetration and also delivery of drugs to less approachable sites including the GI tract, upper nasal cavity, buccal and vaginal cavities [37]. There are so many mucoadhesive polymer used for the fabrication of mucoadhesive drug delivery such as chitosan, thiolated chitosan, PLGA etc. Chitosan is biodegradable and mucoadhesive semi synthetic polymer derived from the naturally occurring chitin present in the exoskeleton of many crustaceans. In different studies it is reported that chitosan has also some antifungal effect, as it can inhibit hyphal growth and spore germination of the various fungi [38].
Mucoadhesive nanoparticles have been widely investigated for the topical delivery of many antimicrobial and antifungal drugs using chitosan as the mucoadhesive polymer which improves the bioavailability of the drugs at the target site.

1.3.1 Advantages of Mucoadhesive Nanoparticles
- Improved drug bioavailability.
- Site specific drug delivery.
- Rapid systemic absorption.
- More rapid onset of therapeutic action.
- Prolonged intimate contact with underlying mucosa.
- To improve the uptake of poorly soluble drugs.
- Less amount of dose required.
- Ease of termination of therapy.
- Decrease drug resistance.
- Less side effects and low toxicity.
- Better patient compliance.

2. Conclusion
This review addresses recent developments in nanomedicines, encompassing both new and old drug delivery technologies and innovative diagnostic approaches. A variety of nano-scale materials, such as nanorobots and nanosensors, have been described. These materials can be used for diagnosis, precise delivery to targets, sensing, or activating materials in real-time systems. Initially, the main goals of using nanotechnology in medicine were to improve the drugs' solubility, absorption, bioavailability, and controlled release.

3. Declaration of interest: The authors were addressing no conflicts of interest.

4. References
1. Syed AA, Rizvi A, Ayman M, Saleh B. Applications of nanoparticle systems in drug delivery technology. Saudi Pharmaceutical Journal. 2018;26:64-70.
2. Kumar S, Dilbaghi N, Saharan R, Bhanjana G. Nanotechnology as emerging tool for enhancing solubility of poorly water-soluble drugs. Bionanoscience. 2012;2(4):227-250.
3. Bamrungsap S, Zhao Z, Chen T, Wang L, Li C, Fu T, *et al*. Nanotechnology intherapeutics: a focus on

nanoparticles as a drug delivery system. Nanomedicine. 2012;7(8):1253-1271.
4. Kohane DS. Microparticles and nanoparticles for drug delivery. Biotechnol Bioeng. 2007;96(2):203-209.
5. Desai MP, Labhasetwar V *et al*. The mechanism of uptake of biodegradable microparticles in Caco-2 cells is size dependent. Pharm Res. 1997;14:1568-1573.
6. McMillan J, Batrakova E *et al*. Cell delivery of therapeutic nanoparticles. Prog. Mol. Biol Transl Sci. 2011;104:563-601.
7. Prokop A, Davidson JM. Nanovehicular intracellular delivery systems. J Pharm Sci. 2008; 97(9):3518–3590.
8. Landesman-Milo D, Goldsmith M, Leviatan BS, Witenberg B, Brown E, Leibovitch S *et al*. Hyaluronan grafted lipid-based nanoparticles as RNAi carriers for cancer cells. Cancer Lett. 2013;334:221-227.
9. Hua S, Wu SY. The use of lipid-based nanocarriers for targeted pain therapies. Front Pharmacol. 2013;4:143.
10. Monteiro N, Martins A, Reis RL, Neves NM. Liposomes in tissue engineering and regenerative medicine. J R Soc Interface. 2014;11:0459.
11. Yingchoncharoen P, Kalinowski DS, Richardson DR. Lipid-based drug delivery systems in cancer therapy: what is available and what is yet to come. Pharmacol Rev. 2016;68:701-787.
12. Kim T, Hyeon T. Applications of inorganic nanoparticles as therapeutic agents, Nanotechnology. 2013;25(1):012001.
13. Liang JJ, Zhou YY, Wu J, Ding Y. Gold nanoparticle-based drug delivery platform for antineoplastic chemotherapy. Curr Drug Metab. 2014;15:620-631.
14. Giner-Casares JJ, Henriksen-Lacey M, Coronado-Puchau M, Liz-Marzan LM. Inorganic nanoparticles for biomedicine: where materials scientists meet medical research. Materials today. 2016;19(1):19-28.
15. Ma M, Chen H, Chen Y, Wang X, Chen F, Cui X, *et al*. Au capped magnetic core/mesoporous silica shell nanoparticles for combined photothermo−/chemo-therapy and multimodal imaging. Biomaterials. 2012;33(3):989-98.
16. Nunez C, Estevez SV, Chantada DPM. Inorganic nanoparticles in diagnosis and treatment of breast cancer. JBIC. 2018;23(3):331-45.
17. Li Z, Ding J, Xiao C, Pan H, Tang Z, Xuan P *et al*. Glucose-sensitive polypeptide micelles for self-regulated insulin release at physiological pH. J Mater Chem. 2012;22:12319-12328.
18. Danhier F, Ansorena E, Silva JM, Coco R, Breton LA, Preat V. PLGA-based nanoparticles: an overview of biomedical applications. J Control Release. 2012;161:505–522.
19. Soppimath KS, Aminabhavi TM, Kulkarni AR, Rudzinski WE. Biodegradable polymeric nanoparticles as drug delivery devices. J Control Release. 2001;70(1-2):1-20.
20. Afsharzadeh M, Hashemi M, Mokhtarzadeh A, Abnous K, Ramezani M. Recent advances in co-delivery systems based on polymeric nanoparticle for cancer treatment. Artif Cells Nanomed Biotechnol. 2018;46:1095-1110.
21. Geszke-Moritz M, Moritz, M. Solid lipid nanoparticles as attractive drug vehicles: composition, properties and therapeutic strategies. Mater Sci Eng C Mater Biol Appl. 2016;68:982-994.
22. Gordillo-Galeano A, Mora-Huertas CE. Solid lipid nanoparticles and nanostructured lipid carriers: A review emphasizing on particle structure and drug release. Eur J Pharm Biopharm. 2018;133:285-308.
23. Pradhan M, Singh D, Murthy SN, Singh MR. Design, characterization and skin permeating potential of Fluocinolone acetonide loaded nanostructured lipid carriers for topical treatment of psoriasis, Steroids. 2015;101:56-63.
24. Svenson S. The dendrimer paradox–high medical expectations but poor clinical translation. Chem Soc Rev. 2015; 44(12):4131-4144.
25. Baker JR. Dendrimer-based nanoparticles for cancer therapy. Hematol. Am. Soc. Hematol. Educ Program; c2009. p. 708-719.
26. Jain K, Kesharwani P, Gupta U, Jain NK. Dendrimer toxicity: Let's meet the challenge. Int J Pharm. 2010;394(1-2):122-42.
27. Cardoso VF, Francesko A, Ribeiro C, Banobre-Lopez M, Martins P, LancerosMendez S *et al*. Advances in magnetic nanoparticles for biomedical applications. Adv Healthc Mater. 2018;7(5):1700845.
28. Lim SY, Shen W, Gao Z. Carbon quantum dots and their applications. Chem Soc Rev. 2015;44(1):362-381.
29. Bosi S, Ros DT, Spalluto G, Prato M. Fullerene derivatives: an attractive tool for biological applications. Eur J Med Chem. 2003;38:913-923.
30. Beuerle F, Lebovitz R, Hirsch A. Antioxidant properties of water-soluble fullerene derivatives. In: Cataldo, F., Da Ros, T. (eds.) Medicinal Chemistry and Pharmacological Potential of Fullerenes and Carbon Nanotubes. Springer, Berlin; c2008. p. 51-78.
31. Martincic M, Tobias G. Filled carbon nanotubes in biomedical imaging and drug delivery. Expert Opin Drug Deliv. 2015;12(4):563-578.
32. Jain S, Singh SR, Pillai S. Toxicity issues related to biomedical applications of carbon nanotubes. J Nanomed Nanotechol. 2012;3(140):2.
33. Morrow DIJ, McCarron PA, Woolfson AD, Donnely RF. Innovative strategies for enhancing topical and transdermal drug delivery. Open Drug Deliv J. 2007;(1)36-59.
34. Patra JK, Das G *et al*. Nano based drug delivery systems: recent developments and future prospects. J Nanobiotechnology. 2018;16:71.
35. Margit DH, Constantia EK, Bernkop-Schnurch A. *In vitro* evaluationof the viscoelastic properties of chitosan–thioglycolic acid conjugates. European Journal of Pharmaceutics and Biopharmaceutics. 2003;55:185-190.
36. Manchanda S, Sahoo PK. Topical delivery of acetazolamide by encapsulating in mucoadhesive nanoparticles. Asian Journal of Pharmaceutical Sciences. 2017;12(6):550-557.
37. Bhatta RS, Chandasana H, Chhonker YS *et al*. Mucoadhesive nanoparticles for prolonged ocular delivery of natamycin: *in vitro* and pharmacokinetics studies. Int J Pharm. 2012;432:105-112.
38. Palma-Guerrero J, Jansson HB, Salinas J, Lopez-Llorca LV. Effect of chitosan on hyphal growth and spore germination of plant pathogenic and biocontrol fungi. J Appl Microbiol. 2008;104(2):541-553.