International Journal of Pharmaceutical Drug Design
IJPDD (October, 2024)
ISSN: 2584-2897
Website: https://ijpdd.org/

Review

A review of Nanoparticles in Drug Delivery: Recent advances and Future Prospects

Vivek Kumar, Neha Yadav, Deepika Jaiswal, Meenu Kannaujiya, Kavita Gupta, Rahul Kumar

Vidushi college of Pharmacy, Gaurabasantpur, Katehri, Ambedkarnagar (U.P)

Katyayani College of Education, Badruddin Nagar Nanu, Meerut

Article History

Received: 01/09/2024
Revised : 28/09/2024
Accepted : 02/10/2024

DOI:
10.62896/ijpdd.1.11.2

Abstract:

Current research into the use of modified nanoparticles in drug delivery systems (DDSs) for therapeutic applications has yielded numerous fascinating nanocarriers. This study investigates the various traditional and modern conveyance techniques for pharmaceutical distribution. Because of the serious drawbacks of traditional DDSs, nanocarriers have garnered extensive attention. Nanocarriers, including polymeric nanoparticles, mesoporous nanoparticles, nanomaterials, carbon nanotubes, dendrimers, liposomes, metallic nanoparticles, nanomedicine, and tailored nanomaterials, are used as transport systems for targeted distribution to specific body regions. Nanomedicine has rapidly grown to treat a wide range of conditions, including brain cancer, lung cancer, breast cancer, cardiovascular illness, and many others. All of these nanocarriers have been studied both in vitro and in vivo. Nanomedicines have the potential to significantly improve human health in the coming years by incorporating more modern techniques into the medication delivery system.

Keywords: *Nanocarriers, Nanomedicine, Nanoparticles drug delivery systems.*

***Corresponding Author**

Rahul Kumar

Katyayani College of Education, Badruddin Nagar Nanu, Meerut

Introduction

Historically, drug delivery systems (DDSs) were employed to treat a variety of illnesses. All medicines treat diseases with pharmacologic active metabolites (drugs). Some medications are intended as inactive precursors that become active when converted in the body. Their efficacy is dependent on the route of administration. Drugs were often administered through oral, nasal, inhalation, mucosal, and injectable techniques in traditional drug delivery systems (CDDSs). Conventionally administered medications were absorbed less, dispersed irregularly, injured unaffected areas, excreted early, and took longer to heal the disease[1]. They were less effective due to a number of obstacles, including enzymatic breakdown or pH disparities, numerous mucosal barriers, off-target effects, and their fast release, which increased toxicity in blood.

For all of these reasons, a controlled-release medication delivery system was created. This development in the DDS improves medication efficacy in a variety of ways [6]. DDSs have been designed in recent years to regulate drug release[2]. These modified DDSs exploited a variety of new ways for controlled medication release into sick regions. The strategies included erodible material, degradable material, matrix, hydrogel, osmotic pump, and reservoir. They all served as a conduit for medicines to reach their intended targets, such as tissues, cells, or organs. In these approaches, medications are frequently available for a wide range of disorders. Such efforts were unsuccessful due to poorer dispersion, lesser solubility, increased drug aggregation, decreased target selection, and poor disease treatment outcomes[3].

Furthermore, drug development is the most costly, complex, and time-consuming procedure. The innovative drug discoveries involved the identification of new chemical entities (NCEs) with important differentiating properties such as drug capability and medicinal chemistry. This process, however, was found to be less effective in terms of total accomplishment percentage , with 40% of medication development bungled due to variable reactions and unexpected toxicity in people. Medication development and delivery have shifted from the micro to the nano level in recent decades, with the goal of increasing life expectancy by modernizing medication delivery technologies[4].

In 1959, Feynman was the first physicist to introduce the concept of nanotechnology in his speech "There's Plenty of oom at the Bottom". This approach sparked significant advances in the field of nanotechnology. Nanotechnology is the study of incredibly small things, and it serves as a center for all science fields such as physics, chemistry, biology, engineering, information technology, electronics, and material science. Nanotechnology-measured structures range in size from 1-100 nm. Nanoparticles have different material characteristics because of their submicroscopic size and also provide practical implementations in a wide range of fields, including engineering, drug delivery, nanomedicine, environmental indemnification, and catalysis, as well as target diseases such as melanoma and cardiovascular diseases (CVD), skin diseases, liver diseases, and many more[5-7].

Nanoparticles, while less effective, can treat cancer by selectively eliminating all malignant cells . In 2015, the FDA approved clinical studies of onivyde nanomedicine for cancer treatment . Nanocarriers have physicochemical features that benefit pharmaceuticals by enhancing solubility, degradation, clearance, targeting, theranostics, and combination therapy[8]. There have been studies on nanomedicine based on protein utilized for drug delivery, in which multiple protein subunits unite to give medicine on-site to a specific tumor. Protein-based podiums, including numerous protein coops, nanoparticles, hydrogels, films, microspheres, tiny rods, and minipellets, are among the many different types and forms of nanocarriers used to transport medicine. All proteins, including ferritin-protein coop, the small heat shock protein (sHsp) cage, plant-derived viral capsids, albumin, soy and whey protein, collagen, and gelatin-implemented proteins, have been described for drug carriage[9].

Recent Approaches Used in Drug Carriage System for Treatment of Various Diseases

Brain Drug Delivery System and Its Types

The blood-brain barrier (BBB) is damaged in the most serious cases of disorders such as strokes, seizures, multiple sclerosis, AIDS, diabetes, glioma, Alzheimer's disease, and Parkinson's disease . The modification of the protein complex in intra-endothelial junctions under pathological settings is a major cause of blood-brain barrier disruption. Normally, the blood-brain barrier prevents macromolecules and micromolecules from entering the brain, thereby maintaining blood-brain equilibrium[10]. If a medicine crosses the BBB, it inhibits its accumulation in the intracerebral region of the brain and reduces its bioavailability, making brain illnesses untreatable . As a result, the best drug delivery system (DDS) is a cell membrane DDS, a virus-based DDS, or an exosome-based DDS intended for BBB penetration, lesion targeting capabilities, and standard safety. The nanocarrier-assisted intranasal medication delivery technology is widely employed to treat brain illnesses.

Drugs that are poorly distributed to the brain can now be loaded into a nanocarrier-based system, which interacts well with endothelial micro vessel cells at the BBB and nasal mucosa to increase drug absorption time and olfactory nerve fibers to stimulate straight nose-to-brain delivery, resulting in greater drug absorption in brain parenchyma via the secondary nose-to-blood-to-brain pathway[11]. The role of nanocarriers in Alzheimer's disease Alzheimer's disease is one of the most rapidly increasing neurological disorders in the senior population[12]. Clinically, it is defined by abstraction, loss of linguistic access, and a decline in spatial skills and reasoning. Furthermore, amyloid β (Aβ) accumulation and anxiety in the brain have a substantial role[13]. Nanotechnology-based medication delivery techniques are used to treat a variety of disorders. Treatments for Alzheimer's disease include polymeric nanoparticles, liposomes, solid lipid nanoparticles, nano-emulsions, micro-emulsions, and liquid crystals[14].

Polymeric nanoparticles

I. The drug. Tacrine was placed onto polymeric nanoparticles and delivered by intravenous method. It increased the concentration of tacrine in the brain while decreasing the overall dose.

II. The rivastigmine medication was placed onto polymeric nanoparticles and delivered intravenously. It improved learning and memory capabilities.

Solid lipid nanoparticles (SLNPs).

SLNPs improved drug retention in the brain, increasing absorption across the BBB. Some of the medication's effects are given below.

I. Piperine medication is packaged onto solid lipid nanoparticles and administered intraperitoneally into the brain to reduce plaques and masses while increasing AChE enzyme activity[15-17].

II. Huperzine Improved cognitive functions. An in vitro investigation found no major irritation in rat skin when the medication was placed onto SLNPs.Recent studies suggest that encapsulating SLNPs with polysorbate improves medication absorption .Some of the coated nanoparticles are given below.

I. Clozapine was loaded onto a Dynasan [Tripalmitin] lipid matrix with surfactant Poloxamer 188 and Epikuron 200 for safe delivery into the brain microenvironment
II. Vitamin A was placed onto a lipid matrix, Glyceryl behenate, and coated with hydroxypropyl distarch to safely cross the BBB.

III. Diminazine was securely delivered to an infected area using a stearic acid matrix covered with polysorbate 80.

IV. Doxorubicin was loaded on stearic acid SLNs coated with Taurodeoxycholate surfactant to deliver the medicine without compromising its potency[18-20].

Liposomes have emerged as promising strategies for brain-targeted medication delivery. Liposomes' recognized benefits include their ability to integrate and transport a vast number of medicines, as well as their ability to adorn their exterior with a variety of ligands. Curcumin-PEG derivatives were loaded onto liposomes and demonstrated excellent affinity for senile plaques in an ex vivo assay. Furthermore, in vitro, it displayed Aβ aggregation and was taken inside by the BBB in a rat model. Folic acid was loaded onto liposomes, delivered via intranasal method, and absorbed through the nasal cavity[21].

The nanoemulsion

I. To improve bioavailability, beta-asarone was placed onto nanoemulsions and delivered intravenously.

Tiny Emulsion

I. By loading tacrine onto a microemulsion, memory was enhanced. These nanoparticles quickly entered the brain through the nose and entered through the intranasal canal.

Crystals in liquid form

I. T. divaricate was injected transdermally after being placed onto liquid crystals. It also enhanced skin infusion and retention, as well as the drug's durability in designs.

Parkinson's disease (PD) and nanocarriers[22]

As the second most prevalent neurological condition, Parkinson's disease has challenges with accurate medication distribution for both diagnosis and therapy. The most interesting issue with levodopa, the traditional anti-

Parkinson's medication, is that it has poor brain transfer and low bioavailability. Nanotechnology steps up to the plate with clever ideas to overcome this problem.

The nanoemulsion

I.By loading beta-asarone onto nanoemulsions and delivering it intranasally, the drug's bioavailability was increased.

Tiny Emulsion

I.Memory was enhanced by tacrine being put onto a microemulsion. These nanoparticles quickly entered the brain through the nose and entered through the intranasal canal.

Crystals in liquid form

I.T. divaricate was administered transdermally after being placed onto liquid crystals. It also enhanced skin infusion and retention, as well as the drug's durability in designs[].

Future of Nanomedicine in Drug Delivery systems

Nanomedicine is currently one of the most exciting fields of research. Over the previous two decades, extensive research in this subject has resulted in the filing of 1500 patents and the completion of several dozens of clinical trials.

The nanoparticles shown in this communication are not homogeneous in size, with some measuring in nanometers and others in submicrometers (more than 100 nm). Further research would focus on materials with greater consistency, as well as drug loading and release capacity. This paper also discusses significant advances in the use of metal-based nanoparticles for diagnostic purposes. The use of these metals, especially gold and silver, in diagnosis and therapy is an area of research that could lead to more widespread use of nanomedicines in the future. One notable source of interest in this area is gold nanoparticles, which appear to be effectively absorbed in soft cancer tissues, making the tumour accessible to radiation-based heat therapy (e.g., in the near infrared region) for selective eradication.

Despite a widespread grasp of nanomedicine's future prospects and nano-drug delivery systems, their actual influence in the healthcare system, including cancer therapy/diagnosis, is limited. This is due to the field being a new area of study, with just two decades of actual research on the subject and many crucial fundamental characteristics still unknown. One major future field of research is to identify fundamental indicators of sick tissues, including important biological markers that enable for absolute targeting without disrupting the normal cellular function. Finally, the application of nanomedicine will develop as we gain a better understanding of diseases at the molecular level, or as a nanomaterial-subcellular scale similar marker identification opens up new paths for new diagnosis/therapy. As a result, understanding the molecular fingerprints of disease will lead to advancements in nanomedicine applications. Beyond what we have indicated in this study using known nanoprobes and nanotheragnostics products, additional research is required for the broad application of nanomedicine.

The concept of controlled release of specific medications at vulnerable areas, technology for assessing these events, drug action in tissues/cellular level, and theoretical mathematical models of prediction have yet to be perfected. Numerous investigations in nanomedicine are focused on biomaterials and formulation studies, which appear to be the early phases of biomedical applications. With an increasing global trend toward more precise medications and diagnostics, the future of nanomedicine and nano-drug delivery technology appears bright[13-14].

There has been a lot of interest in the simple concept of developing nanorobots (and nanodevices) that work in tissue diagnosis and repair with full external control. This has not yet become a reality, but it is a futuristic research project that humanity may be able to achieve in the near future. However, as with their benefits, nanomedicines' potential risks to humans and the ecosystem as a whole necessitate long-term research. As a result, a thorough examination of the potential acute or chronic toxicity effects of novel nanomaterials on humans and the environment 4is required. As nanomedicines become increasingly widespread, their affordability will be an area of research that requires additional attention. Finally, as previously discussed, the regulation of nanomedicines will evolve in tandem with advances in nanomedicine applications[23-24].

Conclusion : The current study examines recent improvements in nanomedicines, including technological advancements in the delivery of old and new pharmaceuticals, as well as novel diagnostic procedures. A variety of nano-dimensional materials, such as nanorobots and nanosensors, have been described as being capable of diagnosing, accurately delivering to targets, sensing, and activating materials in a live system. Initially, nanotechnology was used primarily to improve drug solubility, absorption, bioavailability, and controlled release.The use of nanocarriers formulated with gold, silver, cadmium sulphide, and titanium dioxide polymeric nanoparticles, as well as solid lipid nanoparticles, crystal nanoparticles, liposomes, micelles, superparamagnetic iron oxide nanoparticles, and dendrimers, has significantly increased the efficacy of these natural products.

Novel natural biomaterials have continued to be in high demand due to their biodegradability, biocompatibility, ease of availability, renewable nature, and low toxicity. Beyond identifying such polysaccharides and proteins as natural biopolymers, research into making them more stable in industrial processing environments and biological matrixes via techniques such as crosslinking is one of the most advanced study areas today.

Examples include oleic acid-coated iron oxide nanoparticles for near-infrared diagnostic applications, photodynamic detection of colorectal cancer using alginate and folic acid-based chitosan nanoparticles, the use of cathepsin B as a metastatic process, fluorogenic peptide probes conjugated to glycol chitosan nanoparticles, iron oxide-coated hyaluronic acid as a biopolymeric material in cancer therapy, and dextran, among others.

References :

1. Li S., Zhang H., Chen K., Jin M., Vu S.H., Jung S., He N., Zheng Z., Lee M.S. Applicatio of chitosan/alginate nanoparticle in oral drug delivery systems: Prospects and challenges. *Drug Deliv.* 2022;29:1142–1149. doi: 10.1080/10717544.2022.2058646.
2. Vlachopoulos A., Karlioti G., Balla E., Daniilidis V., Kalamas T., Stefanidou M., Bikiaris N.D., Christodoulou E., Koumentakou I., Karavas E., et al. Poly (Lactic Acid)-Based Microparticles for Drug Delivery Applications: An Overview of Recent Advances. *Pharmaceutics.* 2022;14:359. doi: 10.3390/pharmaceutics14020359.
3. Tibbitt M.W., Dahlman J.E., Langer R. Emerging frontiers in drug delivery. *J. Am. Chem. Soc.* 2016;138:704–717. doi: 10.1021/jacs.5b09974.
4. Builders P.F., Arhewoh M.I. Pharmaceutical applications of native starch in conventional drug delivery. *Starch-Stärke.* 2016;9–10:864–873. doi: 10.1002/star.201500337.
5. Alshammari M.K., Alshehri M.M., Alshehri A.M., Alshlali O.M., Mahzari A.M., Almalki H.H., Kulaybi O.Y., Alghazwni M.K., Kamal M., Imran M. Camptothecin loaded nano-delivery systems in the cancer therapeutic domains: A critical examination of the literature. *J. Drug Deliv. Sci. Technol.* 2022;79:104034. doi: 10.1016/j.jddst.2022.104034. +-
6. Lai H., Liu S., Yan J., Xing F., Xiao P. Facile Fabrication of Biobased Hydrogel from Natural Resources: L-Cysteine, Itaconic Anhydride, and Chitosan. *ACS Sustain. Chem. Eng.* 2020;8:4941–4947. doi: 10.1021/acssuschemeng.0c00774.
7. Marco-Dufort B., Willi J., Vielba-Gomez F., Gatti F., Tibbitt M.W. Environment Controls Biomolecule Release from Dynamic Covalent Hydrogels. *Biomacromolecules.* 2021;22:146–157. doi: 10.1021/acs.biomac.0c00895.
8. Smolensky M.H., Peppas N.A. Chronobiology, drug delivery, and chronotherapeutics. *Adv. Drug Deliv. Rev.* 2018;9–10:828–851.
9. Jamieson L.E., Byrne H.J. Vibrational spectroscopy as a tool for studying drug-cell interaction: Could high throughput vibrational spectroscopic screening improve drug development. *Vib. Spectrosc.* 2017;91:16–30. doi: 10.1016/j.vibspec.2016.09.003.
10. Mak K.K., Pichika M.R. Artificial intelligence in drug development: Present status and future prospects. *Drug Discov. Today.* 2019;24:773–780. doi: 10.1016/j.drudis.2018.11.014.
11. Patra J.K., Das G., Fraceto L.F., Campos E.V.R., Rodriguez-Torres M.D.P., Acosta-Torres L.S., Diaz-Torres L.A., Grillo R., Swamy M.K., Sharma S., et al. Nano based drug delivery systems: Recent

developments and future prospects. *J. Nanobiotechnol.* 2018;16:1–33. doi: 10.1186/s12951-018-0392-8. Jain K.K. Drug delivery systems—An overview. *Drug Deliv. Syst.* 2008;437:1–50

12. Ma C., Peng Y., Li H., Chen W. Organ-on-a-Chip: A new paradigm for drug development. *Trends Pharmacol. Sci.* 2021;42:119–133. doi: 10.1016/j.tips.2020.11.009
13. Su Y., Xie Z., Kim G.B., Dong C., Yang J. Design strategies and applications of circulating cell-mediated drug delivery systems. *ACS Biomater. Sci. Eng.* 2005;4:201–217. 15. Baig N., Kammakakam I., Falath W. Nanomaterials: A review of synthesis methods, properties, recent progress, and challenges. *Mater. Adv.* 2021;2:1821–1871. doi: 10.1039/D0MA00807A.
14. Prasad R.D., Charmode N., Shrivastav O.P., Prasad S.R., Moghe A., Sarvalkar P.D., Prasad N.R. A review on concept of nanotechnology in veterinary medicine. *ES Food Agrofor.* 2021;4:28–60. doi: 10.30919/esfaf481.
15. Lateef A., Darwesh O.M., Matter I.A. *Microbial Nanobiotechnology.* Springer; Singapore: 2021. Microbial nanobiotechnology: The melting pot of microbiology, microbial technology and nanotechnology; pp. 1–19. [
16. Mansor N.I., Nordin N., Mohamed F., Ling K.H., Rosli R., Hassan Z. Crossing the blood-brain barrier: A review on drug delivery strategies for treatment of the central nervous system diseases. *Curr. Drug Deliv.* 2019;16:698–711.
17. Mughal T.A., Ali S., Hassan A., Kazmi S.A.R., Saleem M.Z., Shakir H.A., Nazer S., Farooq M.A., Awan M.Z., Khan M.A., et al. Phytochemical screening, antimicrobial activity, in vitro and in vivo antioxidant activity of Berberis lycium Royle root bark extract. *Braz. J. Biol.* 2021;84
18. Bonifácio B.V., da Silva P.B., dos Santos Ramos M.A., Negri K.M.S., Bauab T.M., Chorilli M. Nanotechnology-based drug delivery systems and herbal medicines: A review. *Int. J. Nanomed.* 2014;9:1–15
19. Astruc D. Introduction to Nanomedicine. *Molecules.* 2016;21:4. doi: 10.3390/molecules21010004
20. Peer D., Karp J.M., Hong S., Farokhzad O.C., Margalit R., Langer R. Nanocarriers as an emerging platform for cancer therapy. *Nano-Enabled Med. Appl.* 2021:61–91. doi: 10.1201/9780429399039-2.
21. Cleal K., He L., Watson P.D., Jones A.T. Endocytosis, intracellular traffic and fate of cell penetrating peptide-based conjugates and nanoparticles. *Curr. Pharm. Des.* 2013;19:2878–2894. doi: 10.2174/13816128113199990297.
22. Mirza A.Z., Siddiqui F.A. Nanomedicine and drug delivery: A mini review. *Int. Nano Lett.* 2014;4:94. doi: 10.1007/s40089-014-0094-7.
23. Dizaj S.M., Jafari S., Khosroushahi A.Y. A sight on the current nanoparticle-based gene delivery vectors. *Nanoscale Res. Lett.* 2014;9:252. doi: 10.1186/1556-276X-9-252.
24. Pandit A, Zeugolis DI. Twenty-five years of nano-bio-materials: have we revolutionized healthcare? Fut Med. 2016;11(9):985–7.

*****