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Perspective

Nano drug delivery-benefits, limitations and future perspective

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ABSTRACT: In many aspects, nanotechnology aids in the enhancement of the pharmacological and therapeutic qualities of traditional medications. Because nanocarriers can pass through the blood-brain barrier, they can be studied at the cellular level. Although nanodrug delivery has several drawbacks, it can adapt to minute alterations in the surrounding cellular environment, which helps to solve a lot of the present drug delivery issues. Strict standards should be developed by regulators to address their shortcomings. It is generally expected that during the coming years, nanotechnology will continue to advance and spread throughout many facets of science and life. The medical sciences will benefit from the applications of nanotechnology, which will include drug delivery systems, patient therapies, and diagnostic tools. Nanotechnology has been investigated thus far for targeted delivery and diagnosis. It is important to remember that the field of nanotechnology will only grow in the future in the healthcare industry. We provide some important insights about nanodrug delivery from this angle.

KEYWORDS: nanotechnology; nanocarriers; drug delivery; targeted therapy; biocompatibility and toxicity

1. Introduction

In the relatively new fields of nanomedicine and nanodelivery systems, materials in the nanoscale range are employed as diagnostic tools or to administer therapeutic substances to specific targeted areas in a controlled manner[1]. With the administration of precise medications that are targeted and site-specific, nanotechnology provides several benefits 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.

Humans have been using natural plant-based products as treatments for a wide range of illnesses since ancient times. Herbs are the primary source of modern medications, based on customary knowledge and usage[2]. Approximately 25% of the primary medicinal chemicals and their derivatives that are now on the market come from natural sources. Natural substances with various molecular origins provide a starting point for the development of new medications.

Creating synthetically accessible lead molecules that mirror the chemistry of their counterparts has been a popular method in natural product-based drug discovery. Natural products have many amazing qualities, including decreased toxicity, astonishing chemical variety, and chemical and biological

capabilities with macromolecular precision. Because of this, they are good leads for the development of new drugs. Additionally, computational research has aided in the development of next-generation drug inventions such as target-based drug delivery and drug discovery, as well as the understanding of drug interactions at the molecular level.

Pharmaceutical firms are reluctant to invest more in drug delivery and discovery processes based on natural products, despite a number of benefits. Instead, they are investigating the libraries of chemical compounds that are now available in order to find new drugs. But currently, a number of serious illnesses, including cancer, diabetes, cardiovascular disease, inflammatory diseases, and microbial infections, are being investigated as potential treatments for natural substances. This is mostly due to the special benefits that come with natural medications, which include reduced toxicity and adverse effects, affordability, and promising therapeutic outcomes. The toxicity and biocompatibility issues surrounding natural substances, however, make their use as medicine more difficult. As a result of these issues, a large number of natural substances are failing to advance past the clinical trial stages. There are several obstacles to overcome when using large-sized materials for drug administration, such as in vivo instability, low solubility and bioavailability, poor body absorption, problems with target-specific delivery and tonic effectiveness, and potentially harmful pharmacological side effects. Therefore, one solution that might address these important problems is the use of novel drug delivery systems that target specific body areas with medications. As a result, nanotechnology is crucial to improved medicine and medication formulations, focusing on the targeted area and successfully delivering controlled drug release. Through the application of nanostructures and nanophases in a variety of scientific domains, particularly in nanomedicine (**Figure 1**) and nano-based drug delivery systems, where such particles are of great interest, nanotechnology has demonstrated its ability to bridge the gap between the biological and physical sciences.

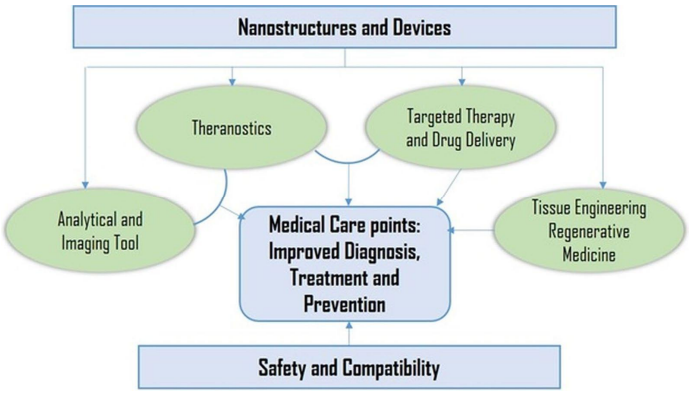

Figure 1. Nanomedicine-overview.

2. Nano-drug delivery system (NDDS)

The number of FDA-approved products and clinical trials based on nanotechnology has skyrocketed since the 1990s. These include liposome formulations, synthetic polymer particles, protein, micellar, and nanocrystal nanoparticles, among many others, frequently in combination with drugs or biologics. Although further research and development will be needed to establish safety and toxicity evaluations and regulatory procedures for nanomedicines, nanomedicine has already completely changed how we find and use medications in biological systems. The development of nanomedicine has made it possible for us to diagnose illnesses and even combine diagnosis and treatment[3–5].

Though the discovery of nanodrugs is fraught with uncertainty and the search for pharmacologically

active compounds in natural sources is not as popular as it was half a century ago, increasing the potency of known naturally occurring bioactive compounds through nanotechnology has become standard practice. A few notable examples of the therapeutic application of nanotechnology include quercetin, ellagic acid, resveratrol, berberine, and curcumin. The more applications there are for nanomaterials, the greater the risk of exposure in clinical settings. This means that there will be more opportunities for nanomaterials to interact with blood vessels, blood, and their constituent parts, which will have a significant effect on human health. With the advancement of nanotechnology, nano-drug delivery systems (NDDSs) offer a novel approach to drug delivery for the treatment of cardiovascular diseases (CVDs), exhibiting significant benefits in resolving the aforementioned issues[6]. However, there are several issues with NDDSs that must be resolved, like cytotoxicity. Gene therapy is one potential application for nano-carriers in CVD drug delivery in the future, which could lead to more ideas for improving cardiovascular medications.

3. Nanodrug carriers

Many intriguing nanocarriers have been created as a result of current research into the function of modified nanoparticles in drug delivery systems (DDSs) for medicinal applications. This essay examines the several drug delivery systems now in use as well as those that have been employed in the past. The nanomaterials employed in NDDSs can be categorized as organic, inorganic, or composite materials based on their material makeup[7]. The many shortcomings of traditional DDSs have sparked a great deal of interest in nanocarriers. For targeted delivery at particular sites of damaged areas in the body, nanocarriers such as polymeric nanoparticles, mesoporous nanoparticles, nanomaterials, carbon nanotubes, dendrimers, liposomes, metallic nanoparticles, nanomedicine, and tailored nanomaterials are utilized as carriage systems (**Figure 2**). The field of nanomedicine has expanded quickly to treat a wide range of illnesses, including cardiovascular disorders, brain, lung, and breast cancer[8]. These nanomedicines have the ability to decrease release times, remove drug agglomeration, increase blood drug solubility, and improve drug bioavailability and absorption time. By improving the therapeutic directories of the energetic pharmacological components incorporated into nanoparticles, nanomedicine has ushered in a new era for medication delivery. In this context, essential knowledge about manufactured nanoparticles was examined and discussed in relation to their potential use in drug delivery systems for the treatment of various illnesses. We examined each of these nanocarriers both in vivo and in vitro. By integrating increasingly sophisticated methods into the medication delivery system, nanomedicines have the potential to enhance human health in the years to come.

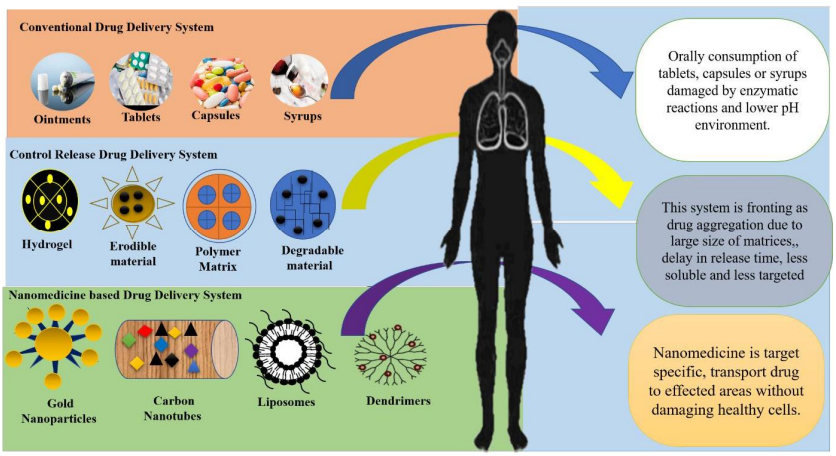

Figure 2. Types of nanodrug carriers-targeted delivery.

In the past, a variety of illnesses have been treated by drug delivery systems (DDSs). To treat illnesses, all medications rely on pharmacologic active metabolites, or pharmaceuticals. Certain medications are intended to be inactive precursors that the body must change into active forms. The administration route affects their efficacy. The most common ways for administering medications in conventional drug delivery systems (CDDSs) were oral, nasal, inhalation, mucosal, and injectable techniques. Conventionally administered medications caused injury to unaffected areas, were excreted early, had a slower rate of absorption, and required longer to cure the illness. Many obstacles, such as their enzymatic breakdown or pH difference, numerous mucosal barriers, off-target effects, and their instant release that increased toxicity in the blood, made them less effective. The development of the controlled-release drug delivery system was motivated by all of these factors. The DDS's evolution improves medication efficacy in a number of ways. Recently, DDSs have been designed to regulate the release of drugs. These altered DDSs released drugs into the sick areas under control using a variety of cutting-edge techniques. These tactics included hydrogel, matrix, osmotic pump, erodible substance, degradable material, and reservoir.

They all offered a means of delivering the medications to the targeted areas, such as organs, tissues, or cells. Drugs for a wide range of illnesses are frequently accessible via these methods. These tactics did not work because of their poor effects on treating diseases, lesser distribution, reduced solubility, more drug aggregation, and less target selectivity. Furthermore, the most costly, complex, and time-consuming procedure is medication development. The novel drug discoveries comprised the discovery of new chemical entities (NCEs) possessing the essential differentiators of pharmaceutical chemistry and drug capability. However, it was determined that this process was less successful overall in terms of accomplishment percentage, as 40% of medication development failed because of the unpredictable nature of the reaction and unexpected toxicity in humans. Drug development and delivery have moved from the micro to the nanoscale in recent decades in an effort to improve drug delivery systems and increase life expectancy. Nanospheres have demonstrated their ability to be reliable drug delivery systems due to their small size. As such, they could be valuable for encasing medications and facilitating more accurate dosing with regulated release.

Using nanoparticles to deliver drugs for specific applications, the promise of tailored, site-specific drug delivery is the most promising. Nanoparticles are the building blocks of bio-nanomaterials, and significant efforts in the design of drug delivery systems are predicated on functionalized nanoparticles. The potential of using nanomaterial-based drug delivery to eradicate a tumorous outgrowth without causing any collateral damage has generated significant interest. They were originally developed as vaccination and anticancer medication carriers. However, by altering the bio-distribution and toxicodynamic of pharmaceuticals, the nanoscale size ranges may greatly improve drug delivery. This can simplify the comparatively simple task of delivering many types of medications that present significant delivery challenges in vivo. One outstanding application of this technology is the modification or functionalization of nanoparticles to target brain tumours with medication delivery through the blood-brain barrier. Doxorubicin, for instance, is not able to pass through the blood-brain barrier, but when combined with polysorbate 80-modified polybutylcyanoacrylate nanoparticles, it can significantly improve brain delivery. Because of their size, structure, and functionality, systems of nanoparticles are essential to the development of DNA delivery vectors. They are effectively absorbed by the cells and have the ability to penetrate deeply into tissues.

One could consider nanoscale colloidal drug carriers to be an advanced advancement in pharmacotherapy. They may serve as possible carriers for a variety of medication classes, including

hormone, anti-cancer, and anti-hypertensive. Submicron colloidal particles have been employed as drug delivery nanoparticles and in medical diagnostic applications. The application of pharmacokinetics for insoluble medicines has been expanded by nanoparticles. For instance, aggregates were generated during the spray drying of the trans-retinoic acid nanoparticle coated with $CaCO_3$, which was created as a novel drug delivery method. It was discovered that the aggregates that had formed would re-disperse in water, which would encourage the islets to secrete insulin. In general, polymeric or inorganic components can make up a nanoparticle.

As individuals became more conscious of the need to treat illnesses, researchers concentrated on getting drugs to the precise location of action at the fastest possible pace. Numerous drug-loaded nanostructures have been shown by certain researchers to be noticeably superior to ordinary nanostructures. However, the performance of the nanostructure depends on the materials it is made of. It must adhere to stringent safety regulations across the globe in order to be used as a component in pharmaceuticals. People have thus focused on readily accessible natural chemicals. To the best of the authors' knowledge, bioactive polysaccharides are ideal options for achieving these goals. Precisely because polysaccharides are naturally occurring, they have been extensively employed in the study of drug-loaded nano-biocarriers. The aforementioned research indicates that there is a lot of promise for upgrading lab-developed nanomaterials into commercial products. Reviewing the most recent developments in drug delivery and the use of polysaccharide-based nano-biocarriers in the treatment of diseases is therefore quite important. The usage of polysaccharide-based nano-biocarriers in the delivery of medications and the treatment of illnesses will grow in the near future.

Currently, oral administration is the most common and effective way to give drugs to humans. Oral medication is not always a successful approach, though, as there are a few issues with how drugs are delivered orally, including poor drug absorption, short residence times, and instability in the gastrointestinal tract (GIT). It is possible to use certain drug delivery techniques to get around these problems. It's interesting to note that when transferring medications, nanoparticles (NPs), a highly stable colloidal polymer, can prevent fast digestion in the GIT. After entering the bloodstream and being absorbed by the intestine, NPs travel to the liver, spleen, and lymph nodes. In the GIT, oral NPs are mostly absorbed by M cells, Peyer plaques, and intercellular, intracellular, and paracellular pathways. It is important to remember that smaller particles are more easily absorbed than bigger ones and that the absorption of NPs is mostly dependent on their size. Studies have shown that adding medications to NPs can significantly increase the drugs' bioavailability in the human body. Compared to traditional oral delivery, the pharmacokinetics and pharmacodynamic effects of medications delivered by oral nanoparticles may differ significantly.

Nanomedicine, which is based on nanotechnology, is a broad discipline that treats diseases. These days, nanotechnology is showing promise as the most effective treatment for all diseases. Researchers at California University are working on ways to get cardiac stem cells into the heart. To enhance the quantity of stem cells in wounded tissue, they affixed nanovesicles that specifically targeted that area. Therefore, the application of stem cells to nanotechnology will lead to the development of several answers for medical problems pertaining to diseases. Many questions are addressed by nanomedicine and nanopharmaceuticals, though. Toxicological and safety assessments, together with irregularities, will be the subject of future research. Demand for nanotechnology will be quite strong. Today, pharmaceutical researchers worldwide are becoming interested in drug-targeted delivery using nanoparticles. All of the negative consequences of conventional treatment will be eliminated by nanomedicine. The National Cancer Institute states that the medical system will use this nanoscale technology to diagnose patients,

deliver therapeutic medications, and identify the spread of cancer. Because 10–200 nm nanoparticles can detect and eliminate SARS-CoV-2 at specific sites and boost the body's immune system, experts are attempting to cure the virus using nanomedicine.

Because nanotechnology prevents viral contamination, it may aid in the fight against COVID-19. In the future, highly precise nano-based sensors will be developed that can identify the virus rapidly and take protective action by spraying the public and front-line clinicians. Furthermore, nanobiotechnology is being used to develop a wide range of antiviral disinfectants to inhibit the spread of viruses. Future developments in nanotechnology will lead to the creation of medications with high activity, low toxicity, and prolonged release to the intended tissue. Thus, both personalized medicine and nanomedicine will be viable treatments for COVID-19 in the future, as well as for other diseases that may arise.

The field of clinical applications for nanoparticle development has grown significantly in the last several years. The limits of free therapies have been addressed by the development of nanoparticles, which can now traverse biological barriers—systemic, microenvironmental, and cellular—that vary depending on the patient population and the ailment. Precision treatments, which use individualized interventions to increase therapeutic efficacy, have also proved successful in overcoming this patient heterogeneity. Nonetheless, the development of nanoparticles still prioritizes the optimization of delivery platforms using a universal approach. Precision medicine can begin to take hold when lipid-based, polymeric, and inorganic nanoparticles are made in ever-more-specific ways and can be tailored for drug delivery (**Figure 3**).

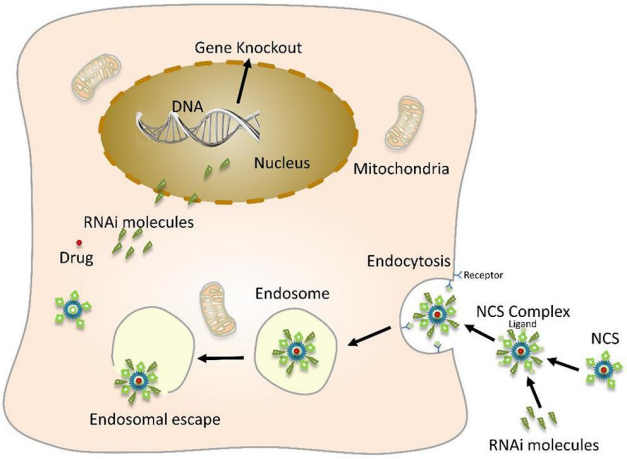

Figure 3. Schematic diagram of nanoparticles-mediated gene and drug delivery.

Engineered nanoparticles have great potential to increase the specificity of treatment and the detection of disease. Through cell-specific targeting, molecular transport to particular organelles, and other strategies, nanotechnology could help overcome the drawbacks of conventional administration, from large-scale problems like biodistribution to smaller-scale obstacles like intracellular trafficking. These factors have led to a proliferation of NP research, which has produced encouraging in vitro and small animal model outcomes. Nevertheless, the quantity of nanomedicines accessible to patients is far less than anticipated for the sector, in part due to a translational gap between animal and human studies. This disparity results from a dearth of knowledge about the physiological and pathological distinctions between human beings and animal model species, particularly with regard to how these distinctions affect the behaviour and usefulness of nanomedicines in the body. There are other factors, besides species differences, that restrict clinical translation. The success of nanomedicines may

also be hampered by patient heterogeneity, and little study has been done thus far on how nanomedicines interact with stratified patient populations. As a result, only a small percentage of licensed nanomedicines are advised as first-line treatments, and many only benefit a small percentage of patients. This is partially caused by the understudied variability in individuals' biological backgrounds and disease-causing factors, which modifies the effectiveness of NPs by changing their distribution and functionality due to changes in the physiology, development, and structure of diseased tissue.

The biological obstacles to delivery were too great for many of the early NP iterations to get past, but more recent NP designs have made use of developments in controlled synthesis methodologies to add targeting agents, complex structures, and bio-responsive moieties to improve delivery. Therefore, these NPs can be used as more complicated systems to target certain phases of the cell cycle, maximize therapeutic efficacy against particular macromolecules, modify various pathways, and overcome mechanisms of drug resistance, particularly in nanocarrier-mediated combination therapies. Part of the reason for this renewed emphasis on developing NPs to get past biological barriers unique to patient subgroups or disease states is the growing popularity of precision, or personalized, medicine and the establishment of the Precision Medicine Initiative (PMI) in 2015. Using patient data to create a customized treatment plan, including genetic profile, environmental exposures, and comorbidities, is the aim of precision medicine. By reducing the effects of patient heterogeneity, precision medicine enables more precise patient stratification, enhanced medication specificity, and optimal dosage or combinatorial approaches. Precision treatments have limited therapeutic potential since they are subject to the same biological hurdles to delivery as other medications. Therefore, the administration of and response to precision medicine medicines could be significantly enhanced by novel NP designs that are driven by patient data and specifically designed to overcome specific obstacles in a stratified patient group.

The preparation procedure for the nanoparticle is chosen based on the drug and the physicochemical properties of the polymer. The following factors determine which matrix material to use: the drug's inherent properties (aqueous solubility and stability), the size of the required nanoparticles, the degree of biodegradability, the antigenicity of the final product, the biocompatibility and toxicity, the desired drug release profile, and surface characteristics (charge and permeability).

Because of their exceptional catalytic capabilities, enzymes are effective instruments for high-efficiency (bio)chemical transformations throughout a broad spectrum[9]. A high degree of substrate promiscuity can be preserved while enantioselective features are retained in the resultant nanobiocatalyst through the careful tailoring of a synthetic shell around an immobilized enzyme with broad substrate specificity. The remarkable substrate and reaction selectivity and high turnover rates of these functioning proteins are the result of the natural evolution of enzymes that have endured 4 billion years of extreme environmental stress. A small number of enzymes, on the other hand, have survived minimal environmental stress in favourable biological niches and have consequently preserved the substrate and catalytic promiscuities of their progenitors.

A broad biocatalytic active site that may accept a multitude of substrates is usually responsible for enabling a high degree of promiscuity when seen from a molecular perspective. Promiscuous enzymes are not as widely used in industry, for example, in the manufacture of chiral compounds, because large active sites also increase the substrate docking flexibility and exhibit low stereoselectivity.

Thanks to recent advances in protein engineering, scientists now have effective techniques to modify the properties of enzymes through the use of directed evolution and rational design. Protein engineering techniques applied to promiscuous enzymes can provide novel reactions or increase biocatalytic

activity[10]. When exposed to various stress conditions, such as high temperatures, freeze-thaw cycles, urea, or sodium dodecyl sulphate treatment, the barrier was made to prevent decreasing protein mobility while boosting enzyme stability.

While enantioselectivity is usually impaired when enzymes are immobilized, a few publications have shown that enantioselectivity can be enhanced when enzymes are encapsulated or immobilized. Cardiovascular diseases (CVDs) are now considered a major danger to human health and survival. For the treatment of CVDs, traditional formulations of several medications with various mechanisms of action are available on the market; however, because of their low biological efficacy, poor water solubility, non-targeting, and drug resistance, they are still far from ideal.

While the targeted design of NDDSs is mostly focused on the diagnosis and treatment of cancer in its early stages, new studies have suggested that lesion cells or tissues of CVDs can also be targeted, and that doing so may be even easier than doing so with tumour tissues that have numerous physiological obstacles. The metabolic half-life of pharmaceuticals, including nanotransporters, in the bloodstream may be extended when compared to standard preparations. It is possible to modify the rate at which those targeted nano-transporter medications function longer by adjusting pH, temperature, light, ultrasound, or biological enzymes. The primary problem that needs to be resolved in the field of nano-biomedicine in the future is how to make nano-drug-loaded particles biocompatible, either directly or through the degradation products of the particles.

Because they demonstrated a number of benefits, polysaccharide-based nanobiocarriers have been extensively utilized in oral drug delivery systems in recent years, garnering a lot of interest. Carbohydrates called polysaccharides are made up of monosaccharides joined by glycosidic linkages. Because they are nanocarriers, polysaccharides are more stable in circulation and can avoid the reticuloendothelial system. It is also possible to alter a number of functional groups in the polysaccharide structure using chemical and biological means. By strengthening their adherence to cells and tissues, the hydrophilic groups in the polysaccharide structure—such as carboxyl, hydroxyl, and amino groups—can increase the drug's bioavailability. It is important to remember that polysaccharide structure and biological activity are strongly correlated. For instance, polysaccharides having a triple helix structure and a medium molecular weight have more immunomodulatory and anti-tumour properties. In addition, the physical characteristics, composition of sugar groups, kinds and ratios of glycosidic bonds, substituent groups, and branched-chain structure of polysaccharides all significantly influence their biological activities, which demonstrate the various health advantages of naturally occurring bioactive polysaccharides.

Because of their many structures and qualities, including their vast molecular weight range, variable reactive groups, and chemical composition, polysaccharides have special qualities. Furthermore, the occurrence of variable derivatization groups—which can be altered to generate various derivatives—is determined by the chemical structure of polysaccharides. Consequently, a number of polysaccharide characteristics, including solubility, biocompatibility, modification potential, and intrinsic biological activity, can enhance their potential for use in nanomedicine. A naturally occurring polymer with strong biocompatibility and biodegradability is polysaccharide[11]. If taken orally, NPs made with natural polysaccharides may be able to preserve medication stability and extend the therapeutic efficacy of the medication. Previous research has demonstrated that the stability of the medications may be better maintained and the length of drug treatment can be increased when NPs made from natural polysaccharides are used to transport drugs. This has significant application prospects. Commonly used polysaccharides as nanocarriers are: chitosan, alginate, dextran, pectin, heparin, cyclodextrin, xanthan gum, pullulan, chondroitin, and hyaluronic acid. Herewith, we summarize the types of nanocarriers with

regard to their physiochemical properties (**Table 1**).

Table 1. Nanocarriers and their physicochemical characteristics.

S/No.	Carrier type	Characteristics
1	Liposomes	Lipid bilayer structure
		Encapsulation of hydrophobic and hydrophilic drugs
		Biocompatible and biodegradable
		Controlled drug release
		Versatile surface modifications for targeting
2	Nanoparticles	Polymeric or inorganic materials
		Tunable size and surface properties
		Sustained drug release
		Can encapsulate various types of drugs
		Potential for passive and active targeting
3	Micelles	Amphiphilic molecules self-assemble into micellar structures
		Improved solubility of hydrophobic drugs
		Enhanced drug stability
		Size can be controlled for targeted drug delivery
4	Dendrimers	Highly branched, tree-like structures
		Precise control over size and shape
		High drug-loading capacity
		Potential for multifunctional surface modifications
5	Carbon nanotubes	Hollow cylindrical structures
		High surface area for drug loading
		Potential for both drug delivery and imaging
		May have issues related to biocompatibility
6	Polymeric nanogels	Three-dimensional network structure
		High water content, resembling natural tissues
		Swelling behaviour for controlled drug release
		Suitable for encapsulating both hydrophobic and hydrophilic drugs

Targeted drug delivery represents a promising avenue for enhancing therapeutic outcomes while minimizing side effects. This article critically evaluates the achievement rates of targeted delivery for a range of nanodrug carriers, including liposomes, polymeric nanoparticles, and dendrimers. The discussion highlights the complexities and advancements in the field, paving the way for a detailed exploration of the physicochemical mechanisms that drive targeted drug delivery at the cellular level.

4. Current status of targeted delivery

This perspective is a comprehensive analysis of the current achievements in targeted drug delivery using nanocarriers. This includes an in-depth examination of the success rates, challenges, and breakthroughs associated with each carrier. For instance, liposomes have shown remarkable progress in delivering drugs to specific cells or tissues, with notable success in cancer therapy. Polymeric nanoparticles, on the other hand, exhibit unique properties for sustained drug release but face challenges in achieving precise targeting[12,13].

5. Physicochemical mechanisms for targeting

From a cell biology perspective, the article elucidates the intricate physicochemical mechanisms underlying targeted drug delivery. The discussion encompasses ligand-receptor interactions, cellular uptake pathways, and intracellular trafficking. Liposomal carriers exploit specific ligands for receptor-mediated endocytosis, ensuring selective uptake by target cells. Polymeric nanoparticles leverage their surface properties to influence cellular internalization pathways, while dendrimers employ their unique dendritic architecture for enhanced cellular penetration and drug release[14–16]. In addition, we present the advantages and disadvantages of NDSS and CDDS (**Tables 2** and **3**).

Table 2. Advantages of NDDS and CDDS.

S/No.	Criteria	Nanoparticulate drug delivery systems (NDDS)	Controlled drug delivery systems (CDDS)
1	Precision in drug targeting	Enables targeted drug delivery to specific cells/tissues	Controlled release allows for sustained therapeutic levels
2	Improved drug solubility and stability	Enhances solubility of poorly water-soluble drugs	Stabilizes labile drugs and reduces side effects
3	Enhanced bioavailability	Increases absorption and bioavailability of drugs	Optimizes drug absorption and prolongs therapeutic effect
4	Targeted and personalized therapy	Facilitates targeted delivery for personalized medicine	Tailors drug release to individual patient needs
5	Potential for combination therapies	Allows for co-delivery of multiple drugs	Enables sequential or simultaneous delivery of drugs

Table 3. Disadvantages of NDDS and CDDS.

S/No.	Criteria	Nanoparticulate drug delivery systems (NDDS)	Controlled drug delivery systems (CDDS)
1	Potential toxicity and biocompatibility issues	Concerns related to nanoparticle toxicity and interactions with biological systems	Potential for adverse reactions or issues with implantation of devices
2	Challenges in large-scale production	Difficulties in scaling up production of nanoparticles	Manufacturing complex delivery systems can be challenging
3	Limited understanding of long-term effects	Long-term safety and biocompatibility may be less understood	Extended exposure to controlled release may have unknown effects
4	Cost considerations	Manufacturing and research costs may be higher	Initial development costs for controlled release systems may be significant

6. Overall summary

Targeted drug delivery systems have emerged as a promising approach in medicine, aiming to enhance therapeutic efficacy while minimizing side effects. By concentrating drugs directly at specific sites in the body, these systems offer advantages such as increased drug efficacy, reduced side effects, improved patient compliance, lower dosage requirements, enhanced bioavailability, and the potential for tailored treatments. However, the complex design and production of these systems pose technological and cost challenges. Additionally, there are concerns regarding limited applicability, biocompatibility issues, the risk of unintended accumulation, and the potential for side effects in targeted tissues. Despite these drawbacks, ongoing research and technological advancements aim to address these challenges and further optimize the potential of targeted drug delivery systems.

7. Future challenges of nanomedicines

Numerous advancements in the field of nanomedicine demonstrate its significance for clinical and other medical aspects. Numerous researchers have looked into the role that nanomedicine plays in treating cancer and lowering rates of morbidity and mortality. But there are also upcoming obstacles that nanomedicines have encountered thus far. The insurance industry, government agencies, and the public health sector will all have concerns about the use of nanomedicine in clinical practice. The FDA hasn't created any particular regulations for goods incorporating nanoparticles as of yet. These research projects are receiving less support from several research organizations across the globe because of other safety concerns and a lack of standardization for nanomaterials.

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Conflict of interest

The authors declare no conflict of interest.

Abbreviations

CDDSs—Conventional drug delivery systems
CVDs—Cardiovascular diseases
DDSs—Drug delivery systems
FDA—Food and drug administration
GIT—Gastrointestinal tract
NCEs—New chemical entities
NDDS—Nano-drug delivery system
NPs—Nanoparticles
PMI—Precision medicine initiative

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