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RESEARCH ARTICLE

Recent advancements in nanoparticles drug delivery systems

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ABSTRACT

Nanoparticles in drug-delivery systems are generated by a variety of research survey. Unique physicochemical characteristics of nanostructured biomaterials include their very small and structural adaptability, high surface area to mass ratio, high reactivity, and controlled size. It enables molecularly focused cancer treatment, targeted administration of early detection of cancer lesions, early detection of cancer lesions, imaging agents, and anticancer medications, identification of tumor molecular factors by non-invasive imaging. These characteristics may be used in medicine to get around some of the drawbacks of conventional treatments. They are employed *in vivo* to protect the drug entity in the systemic circulation, limit drug access to the targeted areas, and deliver the drug to the site of action at a regulated and sustained pace. It reduces adverse side effects and enables more effective drug use. It must be active and therapeutically effective while in circulation and present at the target location in the right amounts. We will now go through several elements of nanoparticle formulation, the impact of their properties, characterization, and the potential of nanomedicine, improving targeted delivery of therapeutic agents, applications in drug molecule delivery, the development of novel, more powerful diagnostic and screening techniques to expand the boundaries of molecular diagnostics, and difficulties in synthesis nanoparticle platforms for dispensing various drugs.

KEY WORDS: Ceramic nanoparticles, Dendrimers, Liposomes, Microbes, Polymeric nanoparticles, Solid lipid nano particles

INTRODUCTION

Materials in the nanoscale range are used as diagnostic instruments or to administer therapeutic compounds to specific targeted regions in a leashedway in the relatively young but quickly evolving field of nanomedicine and nanodelivery systems. These systems are through the targeted and site-specific administration of precise medications. Nanotechnology for several benefits in the treatment of chronic human illnesses. Recent advances in nanomedicine (including, immunotherapeutic agents, biological agents, and chemotherapeutic medicines) for the treatment of different illnesses include severalunique applications. The most common ways to give a drug are by mouth or through an IV. The drug is expected to move through the body and affect both unhealthy and healthy cells and organs. It could cause bad things to happen. Trying to find a way to give a drug to an animal so that it has the most effectiveness while causing the fewest side effects is hard to do. The capacity of drugs to get to the site of therapeutic action limits their potential to have an impact. The bulk of the dosage is dispersed throughout the rest of the body depending on the drug's physicochemical and biochemical

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characteristics, with just a tiny portion of the dose reaching the target location. Colloidal solid particles are known as nanoparticles (1–1000 Aº). Drugs are carefully designed into nanoparticles to absorb or encapsulate them, protecting them from enzymatic and chemical degradation. It can be used as an adjuvant in drugs or vaccines that include active components that also are chemically bound, dissolved, entrapped, encapsulated, or adsorbed. Depending on the manufacturing procedure, the medicine is contained in a cavity surrounded by a special polymeric membrane in nanospheres, nanoparticles, or nanocapsules. Nanospheres are matrix systems that, simultaneously, evenly, and physically distribute the medication.[1] The basic goal in preparing nanoparticles as drug delivery systems is to release pharmacologically active chemicals at the optimal rate and dose for site-specific therapeutic activity.[2] Many researchers studying pharmaceutical controlled release have recently become interested in biodegradable polymeric nanoparticles due to their inherent ability to target specific organs or tissues.

DIFFERENT METHODS OF ADMINISTERING THE DRUG

Drugs may also be supplied by alternative methods, such as transdermal, transmucosal, pulmonary, and implantation, in addition to the oral and injectable routes. Table 1 lists the materials and architectures under investigation for drug delivery applications at the nanoscale.[3]

BENEFITS OVER CONVENTIONAL DRUG DELIVERY

Conventionally, drugs are administered orally or intravenously, causing them to circulate throughout the body and potentially injure cells, tissues, and organs. Because of their permeability through the intestinal epithelium, protein and peptide medicines are quickly absorbed following oral administration. To compensate for limited bioavailability, conventional drug delivery needs high doses.[4] The following are among the benefits of employment as a drug delivery by nanoparticles.

1. Controlled and extended drug release throughout transportation and localization, changing medicine organ distribution and subsequent clearance to maximize therapeutic effectiveness and minimize side effects.
2. Drug incorporation into the system is possible without a chemical reaction, which is essential for drug preservation.
3. It is simple to modify the characteristics of controlled release and drug degradation.
4. No drug is wasted, which implies the drug is more bioavailable at a particular spot in the correct quantity for a longer period.
5. Improves the water solubility of low water-soluble medications, extends the drug's half-life in systemic circulation by decreasing immunogenicity, and decreases the frequency of administration.
6. In comparison to previous approaches, it provides patient comfort and compliance while rising the therapeutic effectiveness of the medication.

Table 1: Currently under investigation for use in drug delivery are materials and structures at the nanoscale

Modern drug delivery methods	Material	Nanostructure forms
Silicon-based	Silicon dioxide	Porous nanoparticles Nano needles
Carbon-based	Carbon	Nanotubes
Metallic	Gold silver platinum	Nanoparticles Nanoshells
Biologic	Lipid peptide nucleic acid polysaccharide	Vesicles nanotubes Nanoparticles

NANOPARTICLES' ROLE IN DRUG DELIVERY

When pharmaceuticals are incorporated into nanoparticles by physical encapsulation, chemical bonding, or adsorption, their pharmacokinetics and therapeutic efficacy may be greatly enhanced over free drug analogs. Nanomaterials provide various benefits for drug regulated and sustained drug release, drug administration, and increased systemic circulation lifespan, including improved serum solubility, drug delivery selectively to tissues and cells of interest, and delivery of multiple therapeutic agents to the same cells for combination therapy.[4,5] Unique physicochemical characteristics of nanostructures, biomaterials, and nanoparticles include their very small and controlled size, structural adaptability, and high reactivity, high surface area to mass ratio. Nanoparticles may enter biological membranes and accessible cells, tissues, and organs. According to Singh *et al.*,[2] traditional drugs, or larger-sized particles, cannot readily pass these cells. According to a report in review Wang *et al.*,[6] drug distribution is significantly influenced by nanobiotechnology, and diverse nanoparticle types have shown novel features that may open up new therapeutic possibilities. Anti-inflammatory medicines have employed drug delivery methods mediated by nanoparticles. The etiology of inflammation has had a significant influence on a variety of illnesses, including inflammatory bowel disease, rheumatoid arthritis, and osteoarthritis. An anti-inflammatory drug dose may be decreased with efficient delivery while the therapeutic impact is improved. In this study, we talk about nanoparticles that could have anti-inflammatory properties and look at how nanomedicine might be used in the future to treat inflammatory illnesses.

SYSTEM FOR MEDICATION DELIVERY USING NANOPARTICLES

In terms of high specificity, controlled release capability, high drug-carrying capacity, high stability, potential application in various methods of drug administration, and the ability to transport both hydrophilic and hydrophobic molecules, nanoparticles can provide significant advantages over conventional delivery techniques. Drugs may be affixed to the surface or incorporated inside the spherical nanoparticles. When the nanoparticle reaches a specific site, the drug payload may be released through erosion, disintegration, or swelling diffusion. In addition, active systems are conceivable, such as those that release a drug in reaction to the application of a specific external source of energy like a magnetic field, ultrasound, or light polymeric nanoparticles,[7] liposomes,[8] solid lipid nanoparticles (SLNs),[9] and Dendrimers,[10] SLNs,[11] and other drug delivery carriers include a variety of nanoparticles that have been intensively researched as antimicrobial drug delivery platforms, with a number of these items already on the market.

DRUGS DELIVERY BY LIPOSOMES

Amphiphilic lipid molecules from the bilayered membrane of liposomes are spherical lipid vesicles. It serves as a nanoparticle for medication delivery. It may be created from synthetic or natural lipids. The most popular antimicrobial drug delivery method at the moment is liposomes.[8,12] The lipid bilayer shape of liposomes, which resembles cell membranes and is easily fused with infectious bacteria, is one of its distinctive characteristics. The pharmacological payloads of liposomes can be delivered to the bacterial interior or cell membranes by directly fusing with the bacterium.[2] Liposomes' lipid bilayer shape easily fuses with bacterial membranes, enabling the medicine to be delivered inside the cell membrane or within the bacterium. There are several effective instances of antimicrobial drug delivery through liposomal carriers. Chemotherapeutic drugs are also often delivered using liposomes.[13] Using self-assembly in conjunction with a modified nanoprecipitation technique, PEG shell, soybean lecithin monolayer, and poly lactic-co-glycolic acid (PLGA), hydrophobic core was developed. The kinetics of drug release were shown to be influenced by the quantity of lipid covering using docetaxel-encapsulated nanoparticles. The findings indicated the potential of PLGA-Lecithin-PEG core-shell nanoparticles for pharmacological controlled release [Table 2].[14,15]

DRUG DELIVERY BY POLYMERIC NANOPARTICLES

Polymers are macromolecules that have a broad range of compositions, structures, and properties because they are made up of numerous repeating units grouped in a chain-like molecular architecture. Polymers are used in nanoparticle systems to develop ideal nanoparticles for each specific biological application due to their vast diversity of compositions, shapes, and properties. Although they are also utilized in bioimaging and biosensing experiments, polymeric nanoparticles are mostly used for medication administration.[16] Biocompatible and biodegradable polymers are often employed in controlled medication release. Size, zeta potentials, and drug release patterns of polymeric nanoparticles may be altered during synthesis using varied polymer lengths, surfactants, and organic solvents.[17] These particles are structurally stable. Polymeric nanoparticles often have functional groups on their surface that may be chemically changed by targeting ligands While the polymerization process is taking place, the medications may either be absorbed into the nanoparticles' surfaces are covalently linked to the nanocapsules.[18]

DRUG DELIVERY BY SLNS

SLN, also known as lipospheres, is a new breed of colloidal drug transporters. These physiologically biocompatible lipids, which are distributed in an aqueous solution and are submicron-sized particles in the 52–100 nm range, stay solid at body and room temperature.[19] Lipids, waxes, and surfactants are primarily used to prepare SLN for emulsification. Fatty acids, triglycerides, steroids, and surfactants are often employed as lipids in the formulation of SLN.[20] Sodium chelate and sodium glycocholate are emulsifiers that help lipid dispersion remain stable. Since they combine several benefits and do not share any drawbacks with other colloidal carriers such as polymeric nanoparticles, liposomes, or lipid immersion, SLN has special qualities that make them an effective drug delivery system. The benefit of using SLN as a medication delivery method is that they are composed of lipids that are physiologically biocompatible and tolerant, making them non-toxic to humans. Drug release may be regulated and tailored for instant or continuous-release. Because the medication is stabilized by solid lipids, when compared to liposomes, the SLN formulation reduces drug leakage while protecting delicate pharmaceuticals from photochemical or oxidative deterioration. Drugs that are both lipophilic and hydrophilic may be encapsulated and administered with few modifications to the SLN formulation. Using the emulsification diffusion approach,[11] it produced the solid lipid nanoparticle-containing cyclosporine.

DRUG DELIVERY BY DENDRIMERS

The macromolecules known as Dendrimers have highly branched polymers and three-dimensional structures, providing a high level of surface utility and adaptability.[21] Dendrimers are spherical macromolecules that have branches that are evenly spaced apart and very well organized. It is made up of a central core, layers of repeat units that branch out from the central core, and functional end groups on the

Table 2: FDA-approved nanomedicine liposome is categorized according to the kind of carrier or ingredient utilized in the formulation

Company name	Ingredientactive	Carrier	Application	Advantage	Year approved
Doxil®/Caelyx™ (Janssen)	Doxorubicin	Liposomes	Karposi'ssarcoma; Ovarian cancer; multiple myeloma	Increase site-specific delivery (tumor) and decrease systemic toxicity	1995; 2005; 2008
Abelcet® (Sigma)	Amphotericin Blipid complex	Liposomes	Fungal infection	Decrease toxicity	1995
DaunoXome® (Galen)	Daunorubicin	Liposomes	Karposi's sarcoma	Increase site-specific delivery	1996
DepoCyt© (Sigma Tau)	Cytarabine	Liposomes	Lymphomatous meningitis	(tumor) and decrease toxicity Increase site-specific delivery	1996
AmBisome® (Gilead Sciences)	AmphotericinB	Liposomes	Infections caused by fungi and protozoa	Lower nephrotoxicity	1997
Curosurf®/Poractant alpha (Chie sei farmaceutici)	ProteinsSP-BandSP-C	Liposomes	Pulmonary surfactant for respiratory distress syndrome and lung activator for stress disorder	Reduced toxicity and improved delivery at a lower amount	1999

repeat units that make up the outermost layer.[22] Dendrimers were originally introduced in 1978 by Fritz Vogtle and his associates. Because Dendrimers are highly branched, they have a high surface area to volume ratio and exhibit strong *in vivo* reactivity with microbes.[23,24] Dendrimers may be filled with both hydrophobic and hydrophilic materials. Hydrophobic drugs may be put into the hydrophobic core's cavity, while hydrophilic drugs might bind to the bivalent surface of Dendrimers through an ionic coupling of electrostatic attraction.[25]

DRUG DELIVERY BY CERAMIC NANOPARTICLES

Because of their controlled- and sustained-release features, subcellular size, and biocompatibility with tissue and cells, ceramic nanoparticles have been widely investigated as particulate carriers in the pharmaceutical and medical industries.[26] The creation of novel ceramic materials for biological applications is now advancing quickly. To lessen their cytotoxicity in biological systems, new synthetic techniques were used to produce nanoscale ceramics such as titanium oxide (TiO_2), zirconia (ZrO_2), and alumina (Al_2O_3) hydroxyapatite (HA), and silica (SiO_2).[27] Inorganic systems having a porous structure are ceramic nanoparticles. Recently, because ceramic nanoparticles are easy to make in the desired size and porosity, there has been a surge in interest in employing them as drug delivery methods.[28] Most of the research has focused on studying common biocompatible ceramic nanoparticles including alumina, titania, and silica. Due to their physiological stability, targeting liver cancer cells using ceramic nanoparticles and DNA are a promising treatment option for cancer therapy [Table 3].[29]

DRUG DELIVERY CARRIERS IN ANOTHER WAY

Organometallic-based structures, including metal colloids, carbon nanotubes, gold Nanoshells, and silica, are examples of such structures that might be used as drug delivery systems. The therapeutic efficacy of many modern medications is great while their water solubility is low. Paclitaxel is one of these medicines. To administer paclitaxel effectively,[33] it employed PEG-coated hydrophilic carbon clusters (40 nm). Because of its numerous special qualities, including variable particle size, shape, and pore size, mesoporous silica nanoparticles have gotten a lot of interest in current years as effective drug delivery carriers. Unlike other organic transporters, they are resistant to bioerosion and biochemical attack. They can hold a lot of drugs, release them slowly, and are stable at high temperatures.[34] Drug delivery was carried out using hollow silica NP. When HSNPs were loaded with the model drug doxorubicin, there was a noticeable sustained drug release.[7,35]

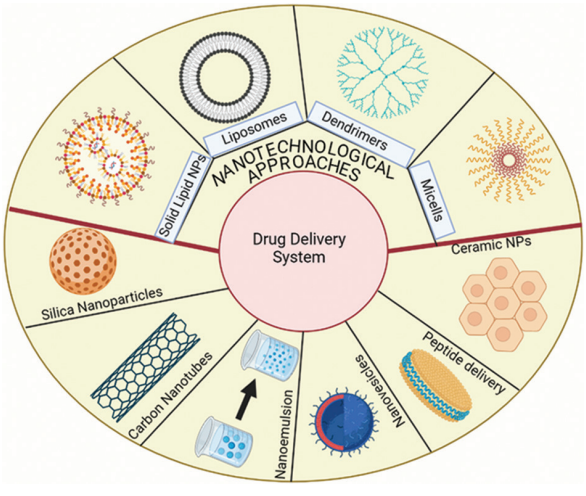

Table 3: Lists nanoparticles for the delivery of antimicrobial

Formulation	Drug	Targeted microorganism	Activity	References
Glyceryl tripalmitate and tyloxapol	Clotrimazole	Fungi (e.g. yeast, *Aspergilli,* Dermatophytes	High physical stability, and chemical in stability when exposed to light	[30]
Stearic acid	Rifampicin, isoniazid, pyrazinamide	*Mycobacterium tuberculosis*	Prolonged drug release, longer residence duration enhanced drug bioavailability reduced frequency of administration, high physical stability, and high encapsulation efficiency	[31]
1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) and cholesterol	PolymyxinB	*Pseudomonas aeruginosa*	Bioavailability is improved, the amount of bacteria in the lungs is reduced, and the amount of bacterial lung damage is decreased	[8]
Glycerol palmitostearate	Econazolenitrate	Fungi	High encapsulation effectiveness and improved drug penetration	[32]
Soybean phosphatidyl choline (PC) and cholesterol	Ampillicin	*Micrococcus luteus* and *Salmonella typhimurium*	Better level of stability Ampicillin showed complete biological action	[12]
Poly-lactide-co-glycolide (PLG) nanoparticle	Rifampicin, isoniazid, pyrazinamide and ethambutol	*Mycobacterium tuberculosis*	Increasing bioavailabilitySuperior pharmacodynamics	[31]
Polyamidoamine (PAMAM) dendrimers	Niclosamide	Tapeworm	Improved solubility in water Controlled drug delivery	[24]
Pegylated lysine-based co polymeric dendrimer	Artemether	*Plasmodium falciparum*	Enhancement of drug stability increased solvability The prolonged half-life of a drug in circulation	[2]

OPPORTUNITIES AND DIFFICULTIES FOR THE FUTURE

The study of nanomedicine is one of the most exciting fields of study right now. Several studies conducted in this field over the past 20 years have already resulted in the filing of 1500 patents and the conclusion of many clinical trials.[36] As the most important tools in nanomedicine, nanoparticles provide significant benefits in drug targeting, distribution, and release. They also have the potential to integrate diagnostic and treatment.[37] The primary objectives are to optimize drug loading, release, interaction with biological barriers transport, and targeting, as well as to make pharmaceuticals more stable in the body. The future studies will undoubtedly focus on increasing biocompatibility since the cytotoxicity of nanoparticles or the products of their breakdown is still a significant.[38,39]

Although nanomedicine and nanodrug delivery systems are well understood, their actual influence on the healthcare system-including in treating and detecting cancer — remains quite restricted. This is due to the field's youth in science, with just two decades of genuine research, and many critical and vital aspects remain unknown. The fundamental indications of sick tissues, such as crucial biological markers that permit absolute targeting without compromising normal cellular function, are a significant area for future study. In the long-term, the usage of nanomedicine will evolve in tandem with our expanding understanding of diseases at the molecular level, or represent a nanomaterial-subcellular scale comparable marker identification to open up new routes for innovative treatment. Therefore, developing nanomedicine applications in the future will need knowledge of the molecular fingerprints of illness.[40] More study is needed to increase the application of nanomedicine beyond what has been stated in review employing the currently existing nanoprobes and nanotheranostics devices.

CONCLUSION

Drug delivery using nanoparticles will have a significant potential influence on society. In addition to reducing the severity of the illness and improving the patient's clinical outcome, The patient's quality of life in terms of health care will be much improved, enable the early diagnosis of pathologic conditions, and increase doctor quality of life.

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