A REVIEW ON NANOPARTICLES

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Abstract

For the past few decades, there has been considerable research interest in the area of drug delivery using particulate delivery systems as carriers for small and large molecules. Particulate systems like nanoparticles have been used as a physical approach to alter and improve the pharmacokinetic and pharmacodynamic properties of various types of drug molecules. They have been used in vivo to protect the drug entity in systemic circulation, restrict access of the drug to the chosen sites, and deliver the drug at a controlled and sustained rate to the site of action. Various polymers have been used in the formulation of nanoparticles for drug delivery research to increase therapeutic benefits while minimizing side effects. Here, we review various aspects of nanoparticle formulation, characterization, the effect of their characteristics, and their applications in the delivery of drug molecules and therapeutic genes.

Keywords: *nanoparticles, drug delivery, targeting, drug release*

INTRODUCTION

Nanoparticles are defined as particulate dispersions or solid particles with a size in the range of 10-1000nm. The drug is dissolved, entrapped, encapsulated, or attached to a nanoparticle matrix. Depending upon the method of preparation, nanoparticles, nanospheres or nanocapsules can be obtained. Nanocapsules are systems in which the drug is confined to a cavity surrounded by a unique polymer membrane, while nanospheres are matrix systems in which the drug is physically and uniformly dispersed. In recent years, biodegradable polymeric nanoparticles, particularly those coated with a hydrophilic polymer such as poly(ethylene glycol) (PEG) known as long-circulating particles, have been used as potential drug delivery devices because of their ability to circulate for a prolonged period time target a particular organ, as carriers of DNA in gene therapy, and their ability to deliver proteins, peptides and genes [1]. The major goals in designing nanoparticles as a delivery system are to control particle size, surface properties, and release of pharmacologically active agents in order to achieve the site-specific action of the drug at the therapeutically optimal rate and dose regimen. Though liposomes have been used as potential carriers with unique advantages including protecting drugs from degradation, targeting to site of action, and reducing toxicity or side effects, their applications are limited due to inherent problems such as low encapsulation efficiency, rapid leakage of a water-soluble drug in the presence of blood components and poor storage stability. On the other hand, polymeric nanoparticles offer some specific advantages over liposomes. For instance, they help to increase the stability of drugs/proteins and possess useful controlled release properties [2] The advantages of using nanoparticles as a drug delivery system include the following:

1. Particle size and surface characteristics of nanoparticles can be easily manipulated to achieve both passive and active drug targeting after parenteral administration.
2. They control and sustain the release of the drug during transportation and at the site of localization, altering organ distribution of the drug and subsequent clearance of the drug so as to achieve an increase in drug therapeutic efficacy and reduction in side effects.
3. Controlled release and particle degradation characteristics can be readily modulated by the choice of matrix constituents. Drug loading is relatively high and drugs can be incorporated into the systems without any chemical reaction; this is an important factor for preserving drug activity.
4. Site-specific targeting can be achieved by attaching targeting ligands to the surface of particles or by the use of magnetic guidance.
5. The system can be used for various routes of administration including oral, nasal, parenteral, intra-ocular, etc.[3]

In spite of these advantages, nanoparticles do have limitations. For example, their small size and large surface area can lead to particle-particle aggregation, making the physical handling of nanoparticles difficult in liquid and dry forms. In addition, small particles size and large surface areas readily result in limited drug loading and burst release. These practical problems have to be overcome before nanoparticles can be used clinically or made commercially available. The present review details the latest development of nanoparticulate drug delivery systems, surface modification issues, drug loading strategies, release control, and potential applications of nanoparticles.[4]

Preparation of Nanoparticles

Nanoparticles can be prepared from a variety of materials such as proteins, polysaccharides, and synthetic polymers. The selection of matrix materials is dependent on many factors including:

(a) Size of nanoparticles required
(b) Inherent properties of the drug, e.g., aqueous solubility and stability.
(c) Surface characteristics such as charge and permeability
(d) Degree of biodegradability, biocompatibility, and toxicity
(e) Drug release profile desired.
(f) Antigenicity of the final product.

Nanoparticles have been prepared most frequently by three methods:

(1) Dispersion of preformed polymers;
(2) Polymerization of monomers; and
(3) Ionic gelation or coacervation of hydrophilic polymers.

However, other methods such as supercritical fluid technology 8 and particle replication in non-wetting templates (PRINT) 9 have also been described in the literature for the production of nanoparticles. The latter was claimed to have absolute control of particle size, shape, and composition, which could set an example for the future mass production of nanoparticles in industry.[5]

Dispersion of preformed polymers:

Dispersion of preformed polymers is a common technique used to prepare biodegradable nanoparticles from poly (lactic acid) (PLA); poly (D, L-glycolide), PLG; poly (D, L-lactide-co-glycolide) (PLGA) and poly (cyanoacrylate) (PCA), 10-12. This technique can be used in various ways as described below.

Solvent evaporation method:

In this method, the polymer is dissolved in an organic solvent such as dichloromethane, chloroform or ethyl acetate which is also used as the solvent for dissolving the hydrophobic drug. The mixture of polymer and drug solution is then emulsified in an aqueous solution containing a surfactant or emulsifying agent to form an oil in water (o/w) emulsion. After the formation of a stable emulsion, the organic solvent is evaporated either by reducing the pressure or by continuous stirring. Particle size was found to be influenced by the type and concentrations of stabilizer, homogenizer speed, and polymer concentration 13. In order to produce small particle size, often a high-speed homogenization or ultrasonication may be employed.[6]

Spontaneous emulsification or solvent diffusion method:

This is a modified version of the solvent evaporation method. In this method, the water-miscible solvent along with a small amount of the water-immiscible organic solvent is used as an oil phase. Due to the spontaneous diffusion of solvents, interfacial turbulence is created between the two phases leading to the formation of small particles. As the concentration of water-miscible solvent increases, a decrease in the size of the particle can be achieved.[7]

Both solvent evaporation and solvent diffusion methods can be used for hydrophobic or hydrophilic drugs. In the case of a hydrophilic drug, a multiple w/o/w emulsion needs to be formed with the drug dissolved in the internal aqueous phase.

Polymerization method

In this method, monomers are polymerized to form nanoparticles in an aqueous solution. The drug is incorporated either by being dissolved in the polymerization medium or by adsorption onto the nanoparticles after polymerization is completed. The nanoparticle suspension is then purified to remove various stabilizers and surfactants employed for polymerization by ultra-centrifugation and re-suspending the particles in an isotonic surfactant-free medium. This technique has been reported for making poly butyl cyanoacrylate or poly (alkyl cyanoacrylate) nanoparticles. Nanocapsule formation and particle size depend on the concentration of the surfactants and stabilizers used [8].

Coacervation or ionic gelation method

Much research has been focused on the preparation of nanoparticles using biodegradable hydrophilic polymers such as chitosan, gelatin, and sodium alginate. Calvo and co-workers developed a method for preparing hydrophilic chitosan nanoparticles by ionic gelation 19, 20. The method involves a mixture of two aqueous phases, of which one is the polymer chitosan, a di-block copolymer ethylene oxide or propylene oxide (PEO-PPO) and the other is a polyanion sodium tripolyphosphate. In this method, the positively charged amino group of chitosan interacts with negatively charged tripolyphosphate to form coacervates with a size in the range of nanometers. Coacervates are formed as a result of electrostatic interaction between two aqueous phases, whereas, ionic gelation involves the material undergoing the transition from liquid to gel due to ionic interaction conditions at room temperature.[9]

Production of nanoparticles using supercritical fluid technology

Conventional methods such as solvent extraction-evaporation, solvent diffusion, and organic phase separation methods require the use of organic solvents which are hazardous to the environment as well as to physiological systems. Therefore, the supercritical fluid technology has been investigated as an alternative to prepare biodegradable micro- and nanoparticles because supercritical fluids are environmentally safe 21. A supercritical fluid can be generally defined as a solvent at a temperature above its critical temperature, at which the fluid remains a single phase regardless of pressure 21. Supercritical CO2 (SC CO2) is the most widely used supercritical fluid because of its mild critical conditions ($T_c = 31.1$ °C, $P_c = 73.8$ bars), non-toxicity, non-flammability, and low price. The most common processing techniques involving supercritical fluids are supercritical anti-solvent (SAS) and rapid expansion of critical solution (RESS). The process of SAS employs a liquid solvent, eg: methanol, which is completely miscible with the supercritical fluid (SC CO2), to dissolve the solute to be micronized; at the process conditions, because the solute is insoluble in the supercritical fluid, the extract of the liquid solvent by supercritical fluid leads to the instantaneous precipitation of the solute, resulting the formation of nanoparticles [10]. Those and Gupta (2005) reported the use of a modified SAS method for the formation of hydrophilic drug dexamethasone phosphate drug nanoparticles for microencapsulation purposes [11].

Effect of Characteristics of Nanoparticles on Drug Delivery

Particle size

Particle size and size distribution are the most important characteristics of nanoparticle systems. They determine the in vivo distribution, biological fate, toxicity, and targeting ability of nanoparticle systems. In addition, they can also influence the drug loading, drug release, and stability of nanoparticles. Many studies have demonstrated that nanoparticles of sub-micron size have a number of advantages over microparticles as a drug delivery system [12]. Generally, nanoparticles have relatively higher intracellular uptake compared to microparticles and are available to a wider range of biological targets due to their small size and relative mobility. Desai et al found that 100 nm nanoparticles had a 2.5-fold greater uptake than 1 µm microparticle, and 6-fold greater uptake than 10 µm microparticles in a Caco-2 cell line [13]. In a subsequent study 26, the nanoparticles penetrated throughout the submucosal layers in a rat in situ intestinal loop model, while microparticles were predominantly localized in the epithelial lining. It was also reported that nanoparticles can cross the blood-brain barrier following the opening of tight junctions by hyperosmotic mannitol, which may provide sustained delivery of therapeutic agents for difficult-to-treat diseases like brain tumors [14]. Tween 80 coated nanoparticles have been shown to cross the blood-brain barrier. In some cell lines, only submicron nanoparticles can be taken up efficiently but not the larger size microparticles.

Currently, the fastest and most routine method of determining particle size is by photon-correlation spectroscopy or dynamic light scattering. Photon-correlation spectroscopy requires the viscosity of the medium to be known and determines the diameter of the particle by Brownian motion and light scattering properties [15]. The results obtained by photon-correlation spectroscopy are usually verified by scanning or transmission electron microscopy (SEM or TEM).

Surface properties of nanoparticles

When nanoparticles are administered intravenously, they are easily recognized by the immune systems and are then cleared by phagocytes from the circulation 34. Apart from the size of nanoparticles, their surface hydrophobicity determines the amount of adsorbed blood components, mainly proteins (opsonins). This in turn influences the in vivo fate of nanoparticles 34, 35. Binding The binding of opsonins onto the surface of nanoparticles called opsonization acts as a bridge between nanoparticles and phagocytes. The association of a drug to conventional carriers leads to modification of the drug biodistribution as it is mainly delivered to the mononuclear phagocytes system (MPS) such as the liver, spleen, lungs, and bone marrow. Indeed, once in the bloodstream bloodstream-modified nanoparticles (conventional nanoparticles) are rapidly opsonized and massively cleared by the macrophages of MMPS-rich org MPS-rich. Generally, it is IgG, a complement that is used for the recognition of foreign substances, especially foreign macromolecules.[16]

Hence, to increase the likelihood of success in drug targeting by nanoparticles, it is necessary to minimize the opsonization and prolong the circulation of nanoparticles in vivo. This can be achieved by (a) surface coating of nanoparticles with hydrophilic polymers/surfactants; (b) formulation of nanoparticles with biodegradable copolymers with hydrophilic segments such as polyethylene glycol (PEG), polyethylene oxide, poloxamer, poloxamine and polysorbate 80 (Tween 80).[17]

Studies show that PEG conformation at the nanoparticle surface is of utmost importance for the opsonin-repelling function of the PEG layer. PEG surfaces in brush-like and intermediate configurations reduced phagocytosis and complement activation whereas PEG surfaces in mushroom-like configurations were potent complement activators and favored phagocytosis [18].

The zeta potential of a nanoparticle is commonly used to characterize the surface charge property of nanoparticles [19]. It reflects the electrical potential of particles and is influenced by the composition of the particle and the medium in which it is dispersed. Nanoparticles with a zeta potential above (+/-) 30 mV have been shown to be stable in suspension, as the surface charge prevents aggregation of the particles. The zeta potential can also be used to determine whether a charged active material is encapsulated within the center of the nanocapsule or adsorbed onto the surface.

Drug loading Ideally, a successful nanoparticulate system should have a high drug-loading capacity thereby reducing the number of matrix materials for administration. Drug loading can be done by two methods:

- Incorporating at the time of nanoparticles production (incorporation method)
- Absorbing the drug after the formation of nanoparticles by incubating the carrier with a concentrated drug solution (adsorption /absorption technique). Drug loading and entrapment efficiency very much depend on the solid-state drug solubility in the matrix material or polymer (solid dissolution or dispersion), which is related to the polymer composition, the molecular weight, the drug-polymer interaction, and the presence of end functional groups (ester or carboxyl) [20]. The PEG moiety has no or little effect on drug loading. The macromolecule or protein shows the greatest loading efficiency when it is loaded at or near its isoelectric point when it has minimum solubility and maximum adsorption. For small molecules, studies show the use of ionic interaction between the drug and matrix materials can be a very effective way to increase drug loading [21].

Drug release to develop a successful nanoparticulate system, both drug release and polymer biodegradation are important consideration factors.

In general, the drug release rate depends on:

(1) Solubility of the drug.
(2) Desorption of the surface-bound
(3) Drug diffusion through the nanoparticle matrix;
(4) Nanoparticle matrix erosion/degradation; and
(5) Combination of erosion/diffusion process. Thus solubility, diffusion, and biodegradation of the matrix materials govern the release process. [22]

In the case of nanospheres, where the drug is uniformly distributed, the release occurs by diffusion or erosion of the matrix under sink conditions. If the diffusion of the drug is faster than matrix erosion, the mechanism of release is largely controlled by a diffusion process. The rapid initial release or ‘burst’ is mainly attributed to weakly bound or adsorbed drugs to the drug surface of nanoparticles [23]. It is evident that the method of incorporation has an effect on the release profile. If the drug is loaded by incorporating the method, the system has a relatively small burst effect and is better sustained [24]. If the nanoparticle is coated by a polymer, the release is then controlled by diffusion of the drug from the core across the polymeric membrane. The membrane coating acts as a barrier to release, therefore, the solubility and diffusivity of drugs in polymer membrane. Because it is the most determining factor in drug release. Furthermore, the release rate can also be affected by ionic interaction between the drug and the addition of auxiliary ingredients. When the drug is involved in interaction with Auxillary ingredients to form a less water-soluble the drug release can be very slow with almost no burst release effect 43; whereas if the addition of auxiliary ingredients e.g., the addition of ethylene oxide-propylene oxide block copolymer (PEO-PPO) to chitosan, reduces the interaction of the model drug bovine serum albumin (BSA) with the matrix material (chitosan) due to competitive electrostatic interaction of PEO-PPO with chitosan, then an increase in drug release could be observed [25].

Various methods which can be used to study the in vitro release of the drug are (1) side-by-side diffusion cells with artificial or biological membranes; (2) dialysis bag diffusion technique; (3) reverse dialysis bag technique; (4) agitation followed by ultracentrifugation/centrifugation; (5) Ultra-filtration or centrifugal ultra-filtration techniques. Usually, the release study is carried out by controlled agitation followed by centrifugation. Due to the time-consuming nature and technical difficulties encountered in the separation of nanoparticles from release media, the dialysis technique is generally preferred [26].

Applications of Nanoparticulate Delivery Systems

Tumor targeting using nanoparticulate delivery systems

The rationale of using nanoparticles for tumor targeting is based on the 1) nanoparticles will be able to deliver a concentrated dose of the drug in the vicinity of the tumor targets via the enhanced permeability and retention effect or active targeting by ligands on the surface of nanoparticles; 2) nanoparticles will reduce the drug exposure of health tissues by limiting drug distribution to the target organ.

When conventional nanoparticles are used as carriers in chemotherapy, some cytotoxicity against the Kupffer cells can be expected, which would result in a deficiency of Kupffer cells and naturally lead to reduced liver uptake and decreased therapeutic effect with intervals of less than 2 weeks administration [27]. Moreover, conventional nanoparticles can also target bone marrow (MPS tissue), which is an important but unfavorable site of action for most anticancer drugs because chemotherapy with such carriers may increase the myelosuppressive effect. Therefore, the ability of conventional nanoparticles to enhance anticancer drug efficacy is limited to targeting tumors at the level of MPS-rich organs. Also, directing anticancer drug-loaded nanoparticles to other tumoral sites is not feasible if a rapid clearance of nanoparticles occurs shortly after intravenous administration[28].

Long circulating nanoparticles

To be successful as a drug delivery system, nanoparticles must be able to target tumors that are localized outside MPS-rich organs. In the past decade, a great deal of work has been devoted to developing so-called “stealth” particles or PEGylated nanoparticles, which are invisible to macrophages or phagocytes. A major breakthrough in the field came when the use of hydrophilic polymers (such as polyethylene glycol, poloxamines, poloxamers, and polysaccharides) to efficiently coat conventional nanoparticle surface produced an opposing effect to the uptake by the MPS. These coatings provide a dynamic “cloud” of hydrophilic and neutral chains at the particle surface which repels plasma proteins[29].

As a result, those coated nanoparticles become invisible to MPS, therefore, remained in the circular for a longer period of time. Hydrophilic polymers can be introduced at the surface in two ways, either by adsorption of surfactants or by the use of block or branched copolymers for the production of nanoparticles.

Studies show nanoparticles containing a coat of PEG not only have a prolonged half-life in the blood compartment but also be able to selectively extravasate in pathological sites such as tumors or inflamed regions with a leaky vasculature [30]. As a result, such long-circulating nanoparticles have increased the potential to directly target tumors located outside MPS-rich regions 51. The size of the colloidal carriers as well as their surface characteristics are the critics of the biological fate of nanoparticles. A size les Size 100 nm and a hydrophilic surface are essential in achieving the reduction of opsonization and subsequent clearance by macrophages 52. Coating conventional nanoparticles with surfactants or PEG to obtain a long-circulating carrier has now been used as a standard strategy for drug targeting in vivo.

Targeting with small ligands appears more likely to succeed since they are easier to handle and manufacture. Furthermore, it could be advantageous when the active targeting ligands are used in combination with the long-circulating nanoparticles to maximize the likelihood of the success in active targeting of nanoparticles [31].

Reversion of multidrug resistance in tumor cells

Anticancer drugs, even if they are located in the tumor intra-tumor, can turn out to be of limited efficacy against numerous solid tumors because cancer cells are able to develop mechanisms of resistance. These mechanisms allow tumors to tumors therapy. Multi-drug resistance (MDR) is one of the most serious problems in chemotherapy. MDR occurs mainly due to the over expire over-expressionism of membrane P-glycoprotein (Pgp), which is capable of extruding various positively charged xenobiotics, including some anticancer drugs, out of cells [32]. In order to restore the tumoral cells’ sensitivity to anticancer drugs by circumventing Pgp-mediated MDR, several strategies including the use of colloidal carriers have been applied. The rationale behind the association of drugs with colloidal carriers, such as nanoparticles, against drug resistance, derives from, the fact that Pgp probably recognizes the drug to be effluxed out of the tumoral cells only when this drug is present in the plasma membrane, and not when it is located in the cytoplasm or lysosomes after endocytosis.

Nanoparticles for oral delivery of peptides and proteins

Significant advances in biotechnology and biochemistry have led to the discovery of a large number of bioactive molecules and vaccines based on peptides and proteins. The development of carriers remains a challenge due to the fact that the bioavailability of these molecules is limited by the epithelial barriers of the gastrointestinal tract and their susceptibility to gastrointestinal degradation by digestive enzymes. Polymeric nanoparticles allow the encapsulation of bioactive molecules and protect them against enzymatic and hydrolytic degradation. For instance, it has been found that insulin-loaded nanoparticles have preserved insulin activity and produced blood glucose reduction in diabetic rats for up to 14 days following oral administration.

The surface area of human mucosa extends to 200 times that of skin [33]. The gastrointestinal tract provides a variety of physiological and morphological barriers against protein or peptide delivery, e.g., (a) proteolytic enzymes in the gut lumen like pepsin, trypsin, and chymotrypsin; (b) proteolytic enzymes at the brush border membrane (endopeptidases); (c) bacterial gut flora; and (d) mucus layer and epithelial cell lining itsel histological architecture of the mucosa is designed to efficiently prevent uptake of particulate matter from the environment. One important strategy to overcome the gastrointestinal barrier is to deliver the drug in a colloidal carrier system, such as nanoparticles, which is capable of enhancing the interaction mechanisms of the drug delivery system and the epithelial [34].

Targeting of nanoparticles to epithelial cells in the GI tract using ligands

Targeting strategies to improve the interaction of nanoparticles with adsorptive enterocytes and M-cells of Peyer's patches in the GI tract can be classified into those utilizing specific binding to ligands or receptors and those based on nonspecific adsorptive mechanisms. The surface mechanisms cytes and M cells display cell-specific carbohydrates, which may serve as binding sites to colloidal drug carriers containing appropriate ligands. Certain glycoproteins and lectins bind selectively to this type of surface structure by a specific receptor-mediated mechanism. Different lectins, such as bean lectin and tomato lectin, have been studied to enhance oral peptide adsorption [35]. Vitamin B-12 absorption from the gut under physiological conditions occurs via receptor-mediated endocytosis. The ability to increase the oral bioavailability of various peptides (e.g., granulocyte colony-stimulating factor, erythropoietin) and particles by covalent coupling to vitamin B-12 has been studied. For this intrinsic process, mucoprotein is required, which is prepared by the mucus membrane in the stomach and binds specifically to cobalamin.

The mucoprotein completely reaches the ileum where resorption is mediated by specific receptors.

Absorption enhancement using non-specific interactions.

In general, the gastrointestinal absorption of macromolecules and particulate materials involves either a paracellular route or an endocytotic pathway. The paracellular route of absorption of nanoparticles utilizes less than 1% of mucosal surface area. Using polymers such as chitosan 68, starch 69, or poly(acrylate) 70 can increase the paracellular permeability of macromolecules. The endocytotic pathway for absorption of nanoparticles is either by receptor-mediated endocytosis, that is, active targeting, or adsorptive endocytosis which does not need any ligands. This process is initiated by the unspecific physical adsorption of material to the cell surface by electrostatic forces such as hydrogen bonding or hydrophobic interactions. Adsorptive endocytosis depends primarily on the size and surface properties of the material. If the surface charge of the nanoparticles is positive or uncharged, it will provide an affinity to adsorptive enterocytes through hydrophobic, whthroughif it is negatively charged and hydrophilic, it shows greater affinity to adsorptive enterocytes and M-cells. This shows that the M-cell's combination of size, surface charge, and hydrophilicity plays a major role in affinity. This is demonstrated with poly (styrene) nanoparticles and when it is carboxylated[36].

Nanoparticles for gene delivery

Polynucleotide vaccines work by delivering genes encoding relevant antigens to host cells where they are expressed, producing the antigenic protein within the vicinity of professional antigen-presenting cells to initiate an immune response. Such vaccines produce both humoral and cell-mediated immunity because intracellular production of protein, as opposed to extracellular deposition, stimulates both arms of the immune system. The key ingredient of polynucleotide vaccines, DNA, can be produced cheaply and has much better storage and handling properties than the ingredients of the majority of protein-based vaccines. Hence, polynucleotide vaccines are set to supersede many conventional vaccines, particularly for immunotherapy. However, there are several issues related to the delivery of polynucleotides that limit their application. These issues include efficient delivery of the polynucleotide to the target cell population and its localization to the nucleus of these cells, and ensuring that the integrity of the polynucleotide is maintained during delivery to the target site [37].

Nanoparticles loaded with plasmid DNA could also serve as an efficient sustained-release gene delivery system due to their rapid escape from the degradative endo-lysosomal compartment to the cytoplasmic compartment [38]. Hedley reported that following their intracellular uptake and endolysosomal escape, nanoparticles could release DNA at a sustained rate resulting in sustained gene expression. This gene delivery strategy could be applied to facilitate bone healing by using PLGA nanoparticles containing therapeutic genes such as bone morphogenic protein.[39]

Nanoparticles for drug delivery into the brain

The blood-brain barrier (BBB) is the most important factor limiting the development of new drugs for the central nervous system. The BBB is characterized by relatively impermeable endothelial cells with tight junctions, enzymatic activity, and active efflux transport systems. It effectively prevents the passage of water-soluble molecules from the blood circulation into the CNS, and can also reduce the brain concentration of lipid-soluble molecules by the function of enzymes or efflux pumps.[40] Consequently, the BBB only permits the selective transport of molecules that are essential for brain function. Strategies for nanoparticle targeting the brain rely on the presence of nanoparticle interaction with specific receptor-mediated transport systems in the BBB. For example, polysorbate 80/LDL, transferrin receptor binding antibody (such as OX26), lactoferrin, cell-penetrating peptides, and melanotransferrin have been shown capable of delivery of a self non-transportable drug into the brain via the chimeric construct that can undergo receptor-mediated transcytosis. It has been reported poly(butyl cyanoacrylate) nanoparticles were able to deliver hexapeptide margin, doxorubicin, and other agents into the brain which is significant because of the great difficulty for drugs to cross the BBB 77. Despite some reported success with polysorbate 80 coated NPs, this system does have many shortcomings including desorption of polysorbate coating, rapid NP degradation, and toxicity caused by the presence of a high concentration of polysorbate[41]. OX26 MAbs (anti-transferrin receptor MAbs), the most studied BBB targeting antibody, have been used to enhance the BBB penetration of liposomes. However, recently, demonstrated that brain uptake of lactoferrin, an iron-binding glycoprotein belonging to the transferrin (Tf) family, is twice that of OX26 and transferrin in vivo. It is possible soon we will see these BBB-specifics used for targeting nanoparticles in the brain.[42]

CONCLUSION

The foregoing show that nanoparticulate systems have great potential, being able to convert poorly soluble, poorly absorbed, and labile biologically active substance into promising deliverable drugs. The core of this system can enclose a variety of drugs, enzymes, and genes and is characterized by a long circulation time due to the hydrophilic shell which prevents recognition by the reticular-endothelial system. To optimize this drug delivery system, a greater understanding of the different mechanisms of biological interactions, and particle engineering, is still required. Further advances are needed in order to turn the concept of nanoparticle technology into a real practical application as the next generation of drug delivery systems.

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