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Nanoparticles based drug delivery system: Recent development in treatment of some chronic diseases

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ABSTRACT

In recent years nanotechnology has proven that nanoparticles acquire a great development in medical applications. Its combination with therapeutic drugs overcomes the limitations of free therapeutics. Further, these systems can deliver drug to specific tissues and provide controlled release therapy. This targeted and sustained drug delivery decreases the drug related toxicity and increases patient's compliance with less frequent dosing. Recently, there are several outstanding applications of nanomedicine in the treatment of various chronic diseases. The current review presents an updated summary of recent advances in the field of nanomedicines and nano-based drug delivery systems. This article emphasize the type of clinically used nanoparticles as well as their current delivery strategies for specific diseases such as cancer, Alzheimer, diabetes Meletus and osteoarthritis.

Introduction

Nanotechnology term was first used in 1970 and has been used to describe production technology in ultra-fine dimensions. It refers to the use, application, and engineering of nanoparticles (NPs). Nano is derived from the Latin word nanous (dwarf). NPs refers to a wide range of materials that include particulate substances, which have one of its three dimensions less than 100 nm (Joudeh & Linke, 2022). Nanomedicine is an application of various nanotechnology techniques to create better solutions to medical problems (Malik *et al*., 2023). Reducing the size of the NP does not improve reactivity, degradability, or productivity, but it can also give unique properties that differ from bulk materials of the same composition (Kuperkar *et al*., 2024). Thanks to these new properties, NP is used in different areas of our lives. Electronics, industry, textile industry, renewable energy, agriculture, food sector, and medicine (Jeevanandam *et al*., 2018). In the medical field, NP offers many new ways to diagnose, treat and prevent diseases (Yavuz and Arslan, 2021). Due to its large specific surface area, NPs has the advantage of loading large amounts of the drug, protecting the drug from enzymatic degradation, thereby improving the stability and efficacy of the drug (Dang and Guan, 2020). After modification of the surface molecule, drug-loaded NPs can be targeted to accumulate in affected cells rather than normal cells, thereby increasing target specificity and reducing drug side effects (Mitchell *et al*., 2021). Ligands such as antibodies, proteins, RNA, and DNA can be bound to the NPs surface to target specific cells. It has become a promising tool for medical applications, such as biomarkers detection, drug delivery, gene therapy, chronic disease therapy, antimicrobial agents, and regenerative medicine (Mitchell *et al*., 2021). According to Ventola (2017), the FDA recommends 50 nano pharmaceutical drug can be used for human.

General structure of NPs

NPs are composed of three different layers: The surface layer, which may be functionalized with a variety of little biomolecules such as metal ions, surfactants, and polymers. The shell layer, which is chemically diverse fabric from the center portion in all aspects. The core, which is basically the central portion of the NP and usually refers to the NP itself (Joseph *et al*., 2023).

Types of therapeutic nanoparticles

NPs are broadly classified into three different categories depending on their shape, size and chemical properties; Carbon nanotubes, Inorganic NPs and Organic NPs.

Carbon nanotubes (CNT)

CNT are elongated, tubular structure, 1–2 nm in diameter made up of carbon and are arranged in graphene sheet form, which is rolled to get cylinder shape.
Carbon-based nanotubes are classified into:
- Single-walled nanotubes (SWNTs): Made up of single graphene cylinder.
- Multi-walled nanotubes (MWNTs): Made up of more than two concentric cylindrical shells of graphene sheets around a central hollow core (Norizan *et al*., 2020).

The CNT can insert themselves readily into bacterial cell membranes and act as potent and selective antibacterial agents cause membrane damage in bacteria cell due to an oxidative stress (Laganà *et al*., 2021) which considered as potential applications of nanotubes as pharmacological antimicrobial agents. The size and surface area of carbon NPs are important parameters affecting their antibacterial activity; that is, increasing the NPs surface area by decreasing their size led to improving their activity for interaction with bacterial cell (Saha and Bal, 2020).

Inorganic NPs (Metallic NPs)

Inorganic-based NPs generally include NPs from a variety of metals and metal oxides. Gold, silver, iron, selenium, zinc, aluminum, cadmium, and copper are the most used to make metallic NPs. On the other hand, examples of inorganic metal oxide-based NPs are zinc oxide, magnesium,

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aluminum oxide, titanium dioxide, copper oxide, cerium oxide, iron oxide, and titanium dioxide. Metal and metal oxide NPs are primarily used in biosensing, bioimaging, and cancer hyperthermia, treatment, and targeted drug delivery (Yadavalli and Shukla, 2017). The excellent antibacterial properties of silver NP make it suitable for use as an antibacterial agent in therapeutic and healthcare products (Bruna *et al*., 2021). Similarly, metal oxides also exhibit antibacterial activity such as TiO2, ZnO, FeO, MnO2, CuO, Al2O3 and play an important role in various medical applications (Kadiyala *et al*., 2018). TiO2 has been used as antibacterial agent for treatment of various infectious diseases (Raj *et al*., 2025). The drug can be attached to the surface of the gold NPs via ionic or covalent and physical absorption, and the release can be delivered and regulated by biological stimulation or photoactivation (Kong *et al*., 2017). Silver NPs are one of the most studied metal NPs due to their recognized anticancer, antibacterial, and antiviral potential, but as far as drug delivery is concerned, the synthesis of silver NP -based drug delivery. Almost no research has been done. System for intracellular administration of doxorubicin and alendronate as anticancer agents to improve the therapeutic index of both anticancer agents (Benyettou *et al*., 2015).

Organic NPs

The group of organic NPs comprises liposomes, micelles, solid lipids, and polymers. The use of organic NPs seems to offer several advantages to facilitate drug or gene delivery to target tissue.

Liposomes

Liposomes are vesicles in which the aqueous core is encapsulated in one or more phospholipid bilayers, which are natural or synthetic phospholipids. Liposomes are effectively absorbed by vascular endothelial cells because the lipid bilayer of liposomes is fundamentally like the cell membrane of cells. Liposomes can capture both hydrophilic and hydrophobic drugs and release them to the appropriate target site. It can cross the blood-brain barrier (BBB) which makes it an innovative tool for drug delivery systems in neurodegenerative diseases (Niu *et al*., 2019). Liposomes are suitable for topical, intravenous, and intramuscular administration, but are rarely suitable for oral administration because they are easily degraded in the gastrointestinal tract. Biocompatibility, biodegradability, and low toxicity are the main advantages of liposome delivery systems (Guimarães *et al*., 2021).

Polymeric NPs

Colloidal particles of size range 20 to 1,000 nm, solid in nature had characteristic core which mostly consists of (chitosan, dextran, gelatin, collagen, albumin, and their derivatives) surrounded with the surfactants (e.g., lecithin) (Zielińska *et al*., 2020). Depending on the manufacturing method, Polymer NP can be structurally divided into nanospheres and nanocapsules. Nanocapsules consist of an oily core dissolved in a drug and are surrounded by a polymer shell that controls the release of the therapeutic drug. Nanospheres are based on a continuous polymer network that can hold the drug inside and adsorb it to the surface (Zielińska *et al*., 2020). They can be divided into two bunches: natural and synthetic polymeric NPs. Natural polymers such as chitosan and albumen are used frequently. Synthetic polymers like Poly (d,l-lactic-co-glycolic acid) (PLGA).

Solid lipid NPs

Like polymeric NPs consisting of core of solid lipid moieties covered by a surfactant stabilized the external core, spherical in shape with diameter ranging from 50 to 1μm. It consists of biocompatible and biodegradable lipids (Geszke-Moritz and Moritz, 2016). Effectively used in many biomedical applications (Bayón-Cordero *et al*., 2019).

Micelles

Micelles are NPs characterized by a hydrophobic core stabilized by a hydrophilic shell. They are highly water soluble due to their hydrophilic shell which could be either phospholipids or poly (L-amino acid). Micelles have long circulation time. It is very effective delivery of therapeutic agent for hydrophobic substances which are stored in the micelle core, where they are solubilized and protected from enzymatic degradation (Ghezzi *et al*.,2021).

Hybrid NPs

Combination of more than one of NPs. For example, mixture of polymeric NP and liposomes that results in a polymer-lipid hybrid system. it has become possible to combine two or more different functionalities in one NPs and their properties can be enhanced or modified by coupling of its different components. It is representing a new trend in biomedical science where the hybrid NPs have great importance due to their high thermal stability, high solubility, and lower toxicity (Singh and Bhateria, 2021).

Modification of NPs

The modification of the NPs allows more control over particles biodistribution, specific-targeting and long-circulation time thanks to the possibility of modifying physico-chemical characters of those NPs. Using liposomes with larger particles can help to exclude it from small capillary vessels and restrict the distribution to larger one. Also, the addition of polyethylene glycol molecules to the lipid surface can 'hide' NPs like liposomes from macrophages and thereby increase the half-life of the particle and allow drug release over a greater period (Hauser *et al*., 2021). The synthesis of multifunctional NPs is a hot investigate theme. Each NP has its own points of interest and drawbacks. In some cases, the properties of NPs are incompatible with drug properties such as binding affinity, crossing the BBB, targeting delivery, and sustained release (Habibi *et al*., 2020). Therefore, by integrating NPs of different physicochemical characters (difference in size, shape, and surface area) leading to synthesis of multicomponent and multifunctional NPs with superior characteristic features (Arafa *et al*., 2020). In same consequence the modification of NPs surface with legend holding binding domains or antibody fragments in addition to drugs, promoting the affinity interaction with specific cell receptors or cell types on diseased tissue (Gavin *et al*., 2014).

Nanomedicine

Owing to the rapid development of nanotechnology, several NPs are involved in our life every day, and the number of NPs products is elevated rapidly. Nanomedicine is one of main fields of nanotechnology which refers to involvement of NPs in diagnosis, monitoring, control, prevention, and disease treatment (Soares *et al*., 2018). Nano-drug delivery systems are a class of NPs that have abilities to increase therapeutic agents characteristic features such as stability, water solubility, prolong circulation time, cellular uptake for target cells, reduce biodegradation, thereby improve the safety, effectiveness and reduce or even avoid the side effects of such drugs (Patra *et al*., 2018; Mitchell *et al*., 2021). Nanodrugs gives opportunity to reach small volume of the therapeutic agents with high cellular drug loading affinity. They are simple to enter the blood vessels without vascular endothelial harm. Thanks to unique physicochemical properties of NPs which are varied from bulk chemical counterparts, these NPs can be used to overcome some of the limitations found in traditional therapeutic agents and diagnostic tools. In the last two decades, several NPs-based therapeutic and diagnostic agents have been developed for the treatment of several chronic diseases such as cancer,

diabetes Meletus and neurodegenerative diseases (Yetisgin *et al*., 2020). In the same sequence these nanoscale agents may provide more effective and/or more convenient routes of administration, lower therapeutic toxicity and extend the product life cycle of conventional drugs (Patra *et al*., 2018). Nano-drug delivery systems have been mainly used in human medicine and while the applications in veterinary medicine are limited, still. However, clinical administration of various nano-drug delivery systems to animals is getting more (Herdiana, 2025).

Applications of NPs in medicine

Various applications of NPs that are involved in medicine include drug delivery system (Nano drug), pharmaceutical therapeutics, biomarker detectors, imaging technique, tissue engineering and regenerative medicine.

Drug delivery system

The main targets for drug delivery system are reaching the drug only to its site of action without effect on healthy tissue, minimizing the side effects of such drug and controlling release of drug to avoid the overdosing or under dosing effect (Chandrakala *et al*., 2022). Drug delivery targeting system is classified into passive, active, and stimuli targeting (Rahim *et al*., 2021).

Passive targeting delivery system

Inflamed or tumors tissues are characterized by leaky blood vessels (this leakage can be triggered by vasodilatory release of histamine in response to inflammation or the newly forming vessel architecture in the tumor environment), a feature that is utilized by NPs which, due to their ultra-tiny size, accumulate in those tissues. In the same order, especially in tumors, the lack of effective lymphatic drainage prevents nanocarriers from escaping the diseased tissue, increasing drug levels within the tumor up to 100-fold compared to healthy cases (Simos *et al*., 2021) Both mechanisms emphasize so-called enhanced permeability and retention (EPR). Liposomes, micelles, and polymers are good candidates for passive targeting.

Active cell targeting

One of the major challenges in drug delivery is the targeted localization of maximum drug doses in injured cells. Targeted delivery system objected to limit the effect of a pharmacological medicate on the diseased tissue. However, this strategy is based on the overexpression of certain biomarkers on the cell membrane of diseased cells (Behera *et al*., 2020). Appropriate ligands need to be added to the surface of the nanocarriers. It is recognized by receptors on the cell membrane. Ligands that bind to the receptor promote endocytosis-mediated cellular uptake of nanocarriers (Nag & Delehanty, 2019). Several cell surface markers targeting NPs, such as biotin, cell-adherent glycoprotein, programmed death ligand 1, folic acid receptor, vascular endothelial growth factor receptor, epidermal growth factor receptor 2, and somatostatin receptors (Simos *et al*., 2021). Overexpressed biotin receptors are considered strong target for multiple drug-targeted delivery systems in cancer treatment, as in the case of leukemia, breast cancer, colon cancer, and lung cancer. Biotin-binding drug molecules can increase the uptake of cancer therapeutics, whereby biotin-binding cancer therapeutics conjugate with their overexpressing receptors on the cell membrane and invade cells via endocytosis (Shi *et al*., 2014). The main drawback facing the target delivery is the immunogenicity of the target ligand which can lead to accelerated blood clearance (Simos *et al*., 2021).

Stimuli-responsive targeting

Therapeutic agents are integrated into specific NPs formulations and released at specific times and locations after being exposed to specific extrinsic (temperature, magnetic, ultrasonic effects) or intrinsic stimuli (pH changes). This improves targeting and improves dose control (Mathiyazhakan *et al*., 2018). For example, cancer cells proliferate, have insufficient oxidative phosphorylation, and have high glucose uptake, resulting in high lactate accumulation and accelerated acidification of the tumor environment. $CaCO_3$-coated nano-metal–organic framework is common example for stimuli targeting where Ca^{2+} ions are decomposed in the acidic tumor environment. The Ca^{2+} ions can then influence the cell membrane to pump Ca^{2+} ATPase, causing cytosolic Ca^{2+} levels to increase and activate calpain-2 to induce cancer cell death (Fang *et al*., 2021).

Cancer nanomedicine

According to the Global Cancer Observatory (The L. Globocan 2018), about 30 million cancer patients die of cancer each year by 2030. Scientists face major challenges in applying chemotherapy in the treatment of cancer. Most important of these is the use of high-dose therapies to achieve efficient doses in tumor tissue that primarily act on healthy cells. Therefore, it is very important to administer high doses of the drug only to the tumor tissue (Blanco *et al*. 2011). At the same time, inadequate blood flow can make it difficult to accumulate enough active ingredients in the tumor, even with necrotic lesions (Cao *et al*. 2011). In same sequence, cancer treatment may moreover come up short due to the high viability of tumor stem cells. It is characterized by high DNA repair capacity, overexpression of anti-apoptotic factors, high hypoxic stability, and overexpression of detoxifying proteins (Vinogradov and Wei, 2012). The use of NPs in cancer therapy can overcome the most of problems facing the chemotherapy, where its use in drug delivery system enable the therapeutic agents to be specifically target the tumor tissue, reducing the required dose of the drug which reflects positively on the general health condition of the patients, also can enable combining more than one drug in the same formulation, detect tumors much faster than traditional diagnostic methods, enable faster healing / recovery, and reduce the risk of infection (Krishnan and George 2014; Elgqvist 2017). Drugs loaded into NPs can be directed to tumor cells through active targeting mechanisms that target specific biological structures that are overexpressed in malignant tissues. Or using passive targeting mechanism depends on the enhancement of cell permeability and retention effect exhibited by some cancer cells. Or through exogenous or endogenous stimuli targeting mechanisms (Behera and Padhi, 2020). For example, in breast cancer the tumor cells have specific properties which could be utilized by NPs for drug delivery targeting mechanism such as higher glucose uptake and lower oxidative phosphorylation leading to over production lactate (acidic pH). pH gradients between the normal tissue (blood physiological pH 7.4) and the tumor site (tumor extracellular pH 6.5) (stimuli target delivery system). In the same sequence, the temperature of tumor tissue raised to 40–42°C due to the increasing rate of glycolysis and rapid cell proliferation). Higher concentration of intracellular glutathione (GSH) 2–3 orders higher than the extracellular GSH which can used in active target mechanism, finally in breast cancer cells, the folate receptors and human epidermal growth factor receptor 2 (HER2) over expressed in tumor cell which can used for target delivery system (Herdiana *et al*.,2021). Doxorubicin as anticancer chemotherapeutic drug conjugated with an anti-HER2 monoclonal antibody is attracted to HER2 receptor (active targeting mechanism). At pH 5, the drug was quickly and fully released from the NPs. the NPs drug delivery system in this case could improve cytotoxicity, selectivity, and efficiency of encapsulation drug (Herdiana *et al* 2021).

Currently, different metal NPs like silver, gold, zinc and copper are integrated into the cure and diagnosis of cancer. The anticancer activity of these NPs is due to the formation of reactive oxygen species (ROS), which

causes cytochrome C and caspase activation, mitochondrial membrane permeabilization, DNA cleavage, and finally apoptosis, auto-phagocytosis, and necrotic death of the cancer cell (Andleeb *et al*., 2021).

Alzheimer nanomedicine

The World Alzheimer's Disease Report (2019) reported that the number of Alzheimer's patients will reach 152 million by 2050 (Lynch *et al*., 2020). The blood brain barrier (BBB) is known to have a major impact in Alzheimer disease (AD) pathogenesis. It is a highly selectively semi-permeable membrane which acts as a structural and chemical barrier to prevent the entry of any foreign substance that aims to invade the brain tissues making it very hard obstacle facing the drugs used in treatment of neuro-degenerative diseases. Carbon nanotubes, Polymer, liposomes, magnetic NPs can easily cross the BBB (Xu *et al*., 2021) making them promising agents for the early diagnosis and curing of neurodegenerative diseases such as AD. In addition, the changes in the physicochemical features of NPs have been created as challenges to encourage movement of their execution for the curing of neurogenerative diseases. For example, binding of NPs with polyethylene glycol and polysaccharides elevate the drug encapsulation bioavailability. Transferrin-conjugated NPs exhibit higher passing across the BBB. Nano-emulsions with oils higher in omega3 poly unsaturated fatty acids, polyclonal antibodies against brain specific antigen, apolipoprotein E attached solid lipid NPs, have all exhibited potent targeting delivery system to the brain tissue (Naqvi *et al*., 2020). Liposomes hold a promising approach against AD. it facilitates loading of hydrophilic lipophilic drugs. To overcome the macrophage attack and opsonization in invivo system, the liposomes are coated with a layer of biomaterial with stealth properties such as polyoxyethylene, cholesterol. These coatings enhance the duration of drug action by prolonging its circulation time and protecting them from immune attack (Faiyaz *et al*., 2021).

Nanomedicine and diabetes mellitus

Diabetes Mellitus (DM) is a common chronic disorder. It is simply defined as an endocrine disorder characterized by a hyperglycemic condition. Polyuria, polydipsia, polyphagia, and weight loss are the major clinical signs of DM (Delicano *et al*., 2020). There are three main types of DM 1. Type 1DM (T1DM) bodies cannot produce insulin (autoantibodies were produced against pancreatic β-cells). 2. Type 2 diabetes (T2DM) The body produces insulin, but the cells are resistant to "insulin resistance." 3. Gestational diabetes is first detected during pregnancy (Elhabush, 2016). Some complications are associated with chronic DM such as retinopathy, diabetic foot, nephropathy, neuropathy, and diabetic cardiomyopathy, which are the leading causes of death (Elhabush, 2016). Some of the disadvantages faced using conventional hypoglycemic anti-diabetes drugs in DM, such as oral administration failure and double insulin injection which considered as the major deterrents facing patient. It is painful and unpleasant. That aside. Inappropriate dosages or timing of this treatment can lead to dangerous hypoglycemia leading to coma and death. Most hypoglycemic agents cause long-term gastrointestinal disorders, diarrhea, renal failure, and hypersensitivity. Therefore, it is momentous to discover new antidiabetic candidates with greater safety but fewer side effects. An alternative route to administer insulin to patients in a more convenient way is needed.

Insulin-coated gold NPs

Gold-NP, in the form of an insulin aspartate-capped gold-NP composite, is used as an inorganic nanocarrier of insulin for the therapeutic potential of DM administered either by intranasal route or oral route. The conjugation of insulin to gold NPs prevented its rapid degradation by the insulin-degrading-enzyme and thus allows controlled and adjustable bioactivity (Shilo *et al*., 2015). The hydrogen bond between insulin and aspartic acid is weaker than the covalent bond between insulin and the direct gold NPs, so the bond between insulin and aspartic acid is used. This makes insulin release easier and faster. This formula can reduce blood sugar levels to 55% via intranasal route (Joshi *et al*., 2006).

Ins-chitosan-vitamin B12- calcium phosphate NP

Chitosan can be used as a natural coating for a variety of NPs due to its unique biodegradability, biocompatibility, and mucosal adhesion. Chitosan is a positively charged polymer that provides maximum adhesion to negatively charged mucosa and cell membranes, thereby increasing cell permeability of enterocytes (Mohammed *et al*., 2017). It is also possible to temporarily open the tight junction of the intestinal epithelium and increase the permeability of this delivered protein (Heidarisasan *et al*., 2018). Chitosan has all the above desirable properties, but it precipitates at neutral to basic pH and cannot be used by oral administration. To overcome this obstacle, chitosan-bound calcium phosphate NPs and vitamin B12 (Ashwni *et al*., 2015), which provide maximum solubilization at neutral and basic pH, make this NP the potential of chitosan vitamin B12-calcium phosphate NPs. VitB12 also showed a target ligand that is significantly involved in pH-dependent insulin release in simulated gastric and intestinal fluid and increased oral bioavailability of insulin (Verma *et al*., 2016). This formula Can be prescribed as a typical nanocarrier to insulin administrated via oral rout (Verma *et al*., 2016).

Liposomal glucagon-like peptide (GLP1)

Glucagon-like peptides are incretin hormones (which induce glucose-dependent postprandial insulin secretion) that result in glucose-dependent insulin release. The main effect of GLP1 is to stimulate insulin and inhibit glucagon secretion, as well as to reduce intestinal motility and secretion and delay gastric emptying. As a result, GLP1 appears as a physiological regulator of appetite and food intake (Araújo *et al*., 2016). GLP1 is currently being evaluated for the treatment of type 2 DM (Araújo *et al*., 2016). GLP1 itself has a short half-life in the gastrointestinal tract due to its rapid degradation by the enzyme dipeptidyl peptidase 4 (DPP4), so oral bioavailability remains a challenge for the pharmaceutical industry (Simos *et al*., 2021). Based on this a liposomal formulation of (dipalmitoyl-phosphatidylglycerol-DPPG) -NPs could be used as nano-carrier provides a protective and stable biocompatible environment for encapsulated (GLP1- and dipeptidyl-peptidase 4 inhibitor (iDPP4). For oral administration, liposomal NPs encapsulated with GLP-1 and iDPP4 are coated with chitosan and a cell-penetrating peptide. it is a short peptide that promotes cellular uptake of molecules that increase transcellular transport. This formulation may be innovative for the oral use of anti-diabetic drugs such as GLP1.

Osteoarthritis and nanomedicine

Joint disease is one of the most common conditions caused by continuous damage to joint tissues such as cartilage, synovium, and subchondral bone. Osteoarthritis is a chronic, irreversible degenerative disease characterized by progressive degeneration of cartilage, inflammation of the synovium, and abnormal reduction of synovial fluid (Martel-Pelletier *et al*., 2016). Intra-articular drug injections are widely used in the treatment of osteoarthritis but reduce the bioavailability of the drug (free drugs are quickly removed from the joint cavity), frequent injections, inflammatory reactions, and potential overdose is a major drawback of these traditional drugs. The non-steroidal anti-inflammatory drug used to treat inflammation associated with osteoarthritis has severe long-term side effects of upset stomach, gastric ulcer, liver, and kidney damage in the long run. Nanomedicine has a great deal of room for the treatment of osteoarthritis. This is because NPs can penetrate deep into the cell

and change the physiology of the cell as needed. NPs encapsulated with anti-inflammatory drugs can prolong the release of these therapeutic agents, increase its bioavailability, ensure sustained release and delivery, optimize doses, and reduce its side effects which are the important goals of osteoarthritis treatment (Mohammadinejad *et al*., 2020). Liposomal NPs are widely used for drug delivery in osteoarthritis due to their biodegradability, biocompatibility, high encapsulation capacity, and ability to capture hydrophilic and lipophilic drugs (Patil and Jadhav, 2014).

Gold nanoparticles

Gold nanoparticles (GNP) exhibit anti-arthritis activity due to their antioxidant and anti-inflammatory properties (Khan *et al*., 2018). Curcumin widely used in arthritis, it has anti-inflammatory and antioxidant effects and downregulates the expression of inflammatory markers (Shep *et al*., 2019). However, the low oral bioavailability of curcumin hinders its therapeutic effect. This is a big problem. Liposomal formulations may increase the cellular uptake of curcumin. GNP tagging with curcumin, followed by curcumin GNP encapsulated in dipalmitoylphosphatidylcholine (DPPC) liposomes, can be used as a modified target delivery system for the treatment of osteoarthritis, increasing bioavailability of the drug by intra-articular injection and provides sustained release (Sarkar *et al*., 2019).

Curcumin

Hyaluronic acid (HA) is the main component of articular cartilage and synovial fluid. Intra-articular injection of extrinsic HA plays an important role in the treatment of osteoarthritis due to its lubricating and anti-inflammatory effects, as endogenous HA disintegrates as osteoarthritis progresses (Bowman *et al*., 2018). Faster degradation and inability to localize to the cartilage surface are the main drawbacks facing using HA to treat osteoarthritis. As a future application of NPs in osteoarthritis the curcumin as strong antioxidant and inflammatory will loaded with HA and both are encapsulated in chitosan polymeric NPs. This formula can be used as targeted delivery system for the treatment of osteoarthritis, injected via intra-articular route increased the drug bioavailability. HA and curcumin may synergistically suppress the development of osteoarthritis (Charan *et al*., 2021).

Conclusion

Nanotechnology is a truly interdisciplinary science, with chemists, physicists, biologists and pharmacists all playing an important role in the development of new therapies and diagnostics. From this review, the application of nanotechnology in drug delivery and medical care has opened new avenues and opened many doors to the provision of customizable and safe treatment options. Nanotechnology encapsulates drugs and / or tracer compounds in NPs for direct delivery to target tissues while reducing toxicity by avoiding accumulation and consequent side effects in healthy tissues. Will try to increase efficiency. Encapsulation of the drug also allows for their controlled release and avoids peaks at concentrations that are very harmful or below therapeutic doses. In addition, NPs have proven to be a major issue in bringing new drugs to market, as they are of great value in the delivery of low-water-soluble drugs and limit bioavailability in the body. Nanoparticles can be manufactured using a variety of materials, depending on the intended function of the system.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Andleeb, A., Andleeb, A., Asghar, S., Zaman, G., Tariq, M., Mehmood, A., Nadeem, M., Hano, C., Lorenzo, J.M., Abbasi, B.H., 2021. A Systematic Review of Biosynthesized Metallic Nanoparticles as a Promising Anti-Cancer-Strategy. Cancers 13, 2818. https://doi.org/10.3390/ cancers13112818.

Arafa, M.G., Girgis, G.N.S., El-Dahan, M.S., 2020. Chitosan-Coated PLGA Nanoparticles for Enhanced Ocular Anti-Inflammatory Efficacy of Atorvastatin Calcium. Int J Nanomedicine15, 1335-1347

Araujo, F., Shrestha, N., Gomes, M.J., Herranz-Blanco, B., Liu, D., Hirvonen, J.J., Granja, P.L., Santos, H.A., Sarmento, B., 2016. In vivo dual-delivery of glucagon like peptide-1 (GLP-1) and dipeptidyl peptidase-4 (DPP4) inhibitor through composites prepared by microfluidics for diabetes therapy. Nanoscale 8, 10706-10713.

Verma, A., Sharma, S., Gupta, P.K., Singh, A., Teja, B.V., Dwivedi, P., Gupta, G.K., Trivedi, R., Mishra, P.R., 2016. Vitamin B12 functionalized layer by layer calcium phosphate nanoparticles: A mucoadhesive and pH responsive carrier for improved oral delivery of insulin. Acta Biomaterialia 31, 288-300.

Bayón-Cordero, L., Alkorta, I., Arana, L., 2019. Application of solid lipid nanoparticles to improve the efficiency of anticancer drugs. Nanomaterials 9, 474.

Behera, A., Padhi, S., 2020. Passive and active targeting strategies for the delivery of the camptothecin anticancer drug: a review. Environmental Chemistry Letters 18, 1557-1567.

Benyettou, F., Rezgui, R., Ravaux, F., Jaber, T., Blumer, K., Jouiad, M., Motte, L., Olsen, J.C., Platas-Iglesias, C., Magzoub, M., Trabolsi, A., 2015. Synthesis of silver nanoparticles for the dual delivery of doxorubicin and alendronate to cancer cells. Journal of Materials Chemistry B 3, 7237-7245.

Blanco, E., Hsiao, A., Mann, A.P., Landry, M.G., Meric-Bernstam, F., Ferrari, M., 2011. Nanomedicine in cancer therapy: innovative trends and prospects. Cancer science 102, 1247-1252.

Bowman, S., Awad, M.E., Hamrick, M.W., Hunter, M., Fulzele, S., 2018. Recent advances in hyaluronic acid based therapy for osteoarthritis. Clinical and Translational Medicine 7, 6.

Bruna, T., Maldonado-Bravo, F., Jara, P., Caro, N., 2021. Silver nanoparticles and their antibacterial applications. International Journal of Molecular Sciences 22, 7202.

Cao, Y., Wang, B., Lou, D., Wang, Y., Hao, S., Zhang, L., 2011. Nanoscale delivery systems for multiple drug combinations in cancer. Future Oncology 7, 1347-1357.

Chandrakala, V., Aruna, V., Angajala, G., 2022. Review on metal nanoparticles as nanocarriers: Current challenges and perspectives in drug delivery systems. Emergent Materials 5, 1593-1615.

Charan, T.R., Bhutto, M.A., Bhutto, M.A., Tunio, A.A., Khuhro, G.M., Khaskheli, S.A., Mughal, A.A., 2021. "Nanomaterials of curcumin-hyaluronic acid": their various methods of formulations, clinical and therapeutic applications, present gap, and future directions. Future Journal of Pharmaceutical Sciences 7, 126.

Dang, Y., Guan, J., 2020. Nanoparticle-based drug delivery systems for cancer therapy. Smart Materials in Medicine 1, 10-19.

Delicano, R.A., Hammar, U., Egenvall, A., Westgarth, C., Mubanga, M., Byberg, L., Fall, T., Kennedy, B., 2020. The shared risk of diabetes between dog and cat owners and their pets: register based cohort study. Bmj 2020, 371.

Elgqvist, J., 2017. Nanoparticles as theranostic vehicles in experimental and clinical applications—focus on prostate and breast cancer. International Journal of Molecular Sciences 18, 1102.

Elhabush, N.A.O., 2016. Applications of inorganic nanoparticles in diabetes (Master's thesis, Colorado State University).

Faiyaz, M., Ganayee, M.A., Akhtar, S., Krishnan, S., Flora, B., Dogra, D., Jha, N.K., Chellappan, D.K., Negi, P., Dua, K., Kesari, K.K., 2021. Nanomaterials in Alzheimer's disease treatment: a comprehensive review. Frontiers in Bioscience-Landmark 26, 851-865.

Fang, Z., Shen, Y., Gao, D., 2021. Stimulus-responsive nanocarriers for targeted drug delivery. New Journal of Chemistry 45, 4534-4544.

Noble, G.T., Stefanick, J.F., Ashley, J.D., Kiziltepe, T., Bilgicer, B., 2014. Ligand-targeted liposome design: challenges and fundamental considerations. Trends in Biotechnology 32, 32-45.

Geszke-Moritz, M., Moritz, M., 2016. Solid lipid nanoparticles as attractive drug vehicles: Composition, properties and therapeutic strategies. Materials Science and Engineering: C 68, 982-994.

Ghezzi, M., Pescina, S., Padula, C., Santi, P., Del Favero, E., Cantù, L., Nicoli, S., 2021. Polymeric micelles in drug delivery: An insight of the techniques for their characterization and assessment in biorelevant conditions. Journal of Controlled Release 332, 312-336.

Guimarães, D., Cavaco-Paulo, A., Nogueira, E., 2021. Design of liposomes as drug delivery system for therapeutic applications. International journal of pharmaceutics 601, 120571.

Habibi, N., Christau, S., Ochyl, L.J., Fan, Z., Hassani Najafabadi, A., Kuehnhammer, M., Zhang, M., Helgeson, M., von Klitzing, R., Moon, J.J., Lahann, J., 2020. Engineered ovalbumin nanoparticles for cancer immunotherapy. Advanced Therapeutics 3, 2000100.

Hauser, P.V., Chang, H.M., Yanagawa, N., Hamon, M., 2021. Nanotechnology, nanomedicine, and the kidney. Applied Sciences 11, 7187.

Heidarisasan SH, Ziamajidi N, Karimi J, Abbasalipourkabir R. Effects of insulin-loaded chitosan-alginate nanoparticles on RAGE expression and oxidative stress status in the kidney tissue of rats with type 1 diabetes. Iran. J. Basic Med. Sci. 21, 1035-1042.

Herdiana, Y., Wathoni, N., Shamsuddin, S., Joni, I.M., Muchtaridi, M., 2021. Chitosan-based nanoparticles of targeted drug delivery system in breast cancer treatment. Polymers 13, 1717.

Jeevanandam, J., Barhoum, A., Chan, Y.S., Dufresne, A., Danquah, M.K., 2018. Review on nanoparticles and nanostructured materials: history, sources, toxicity and regulations. Beilstein Journal of Nanotechnology 9, 1050-1074.

Joseph, T.M., Kar Mahapatra, D., Esmaeili, A., Piszczyk, Ł., Hasanin, M.S., Kattali, M., Haponiuk, J., Thomas, S., 2023. Nanoparticles: taking a unique position in medicine. Nanomaterials 13, 574.

Joshi, H.M., Bhumkar, D.R., Joshi, K., Pokharkar, V., Sastry, M., 2006. Gold nanoparticles as carriers for efficient transmucosal insulin delivery. Langmuir. 2006 Jan 3;22(1):300-5. doi: 10.1021/la051982u.

Joudeh, N., Linke, D., 2022. Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists. Journal of Nanobiotechnology 20, 262.

Kadiyala, U., Kotov, N.A., VanEpps, J.S., 2018. Antibacterial metal oxide nanoparticles: challenges in interpreting the literature. Current Pharmaceutical Design 24, 896-903.

Khan, M.A., Khan, M.J., 2018. Nano-gold displayed anti-inflammatory property via NF-kB pathways by suppressing COX-2 activity. Artificial Cells, Nanomedicine, and Biotechnology 46, 1149-1158.

Kong, F.Y., Zhang, J.W., Li, R.F., Wang, Z.X., Wang, W.J., Wang, W., 2017. Unique roles of gold nanoparticles in drug delivery, targeting and imaging applications. Molecules 22, 1445.

Krishnan, S.R., George, S.K., 2014. Nanotherapeutics in Cancer Prevention, Diagnosis and. Pharmacology and Therapeutics 233.

Kuperkar, K., Atanase, L.I., Bahadur, A., Crivei, I.C., Bahadur, P., 2024. Degradable polymeric bio (nano) materials and their biomedical applications: A comprehensive overview and recent updates. Polymers 16, 206.

Laganà, P., Visalli, G., Facciolà, A., Ciarello, M.P., Laganà, A., Iannazzo, D., Di Pietro, A., 2021. Is the antibacterial activity of multi-walled carbon nanotubes (MWCNTs) related to antibiotic resistance? An assessment in clinical isolates. International Journal of Environmental Research and Public Health 18, 9310.

Malik, S., Muhammad, K., Waheed, Y., 2023. Emerging applications of nanotechnology in healthcare and medicine. Molecules 28, 6624.

Martel-Pelletier, J., Barr, A.J., Cicuttini, F.M., Conaghan, P.G., Cooper, C., Goldring, M.B., Goldring, S.R., Jones, G., Teichtahl, A.J., Pelletier, J.P., 2016. Osteoarthritis. Nature reviews Disease primers 2, 1-18.

Mathiyazhakan, M., Wiraja, C., Xu, C., 2018. A concise review of gold nanoparticles-based photo-responsive liposomes for controlled drug delivery. Nano-micro Letters 10, 10.

Mitchell, M.J., Billingsley, M.M., Haley, R.M., Wechsler, M.E., Peppas, N.A., Langer, R., 2021. Engineering precision nanoparticles for drug delivery. Nature Reviews Drug Discovery 20(2), 101-124.

Mohammadinejad, R., Ashrafizadeh, M., Pardakhty, A., Uzieliene, I., Denkovskij, J., Bernotiene, E.,

Janssen, L., Lorite, G.S., Saarakkala, S., Mobasheri, A., 2020. Nanotechnological strategies for osteoarthritis diagnosis, monitoring, clinical management, and regenerative medicine: recent advances and future opportunities. Current Rheumatology Reports 22, 12.
Mohammed, M.A., Syeda, J.T., Wasan, K.M., Wasan, E.K., 2017. An overview of chitosan nanoparticles and its application in non-parenteral drug delivery. Pharmaceutics 9, 53.
Raj, L.A., Annushrie, A., Namasivayam, S.K.R., 2025. Anti bacterial efficacy of photo catalytic active titanium di oxide (TiO2) nanoparticles synthesized via green science principles against food spoilage pathogenic bacteria. The Microbe 7, 100331.
Nag, O.K., Delehanty, J.B., 2019. Active cellular and subcellular targeting of nanoparticles for drug delivery. Pharmaceutics 11, 543.
Naqvi, S., Panghal, A., Flora, S.J.S., 2020. Nanotechnology: a promising approach for delivery of neuroprotective drugs. Frontiers in Neuroscience 14, 494.
Niu, X., Chen, J., Gao, J., 2019. Nanocarriers as a powerful vehicle to overcome blood-brain barrier in treating neurodegenerative diseases: Focus on recent advances. Asian journal of Pharmaceutical Sciences 14, 480-496.
Norizan, M.N., Moklis, M.H., Demon, S.Z.N., Halim, N.A., Samsuri, A., Mohamad, I.S., Knight, V.F., Abdullah, N., 2020. Carbon nanotubes: Functionalisation and their application in chemical sensors. RSC Advances 10, 43704-43732.
Patil, Y.P., Jadhav, S., 2014. Novel methods for liposome preparation. Chemistry and Physics of lipids 177, 8-18.
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., Habtemariam, S., 2018. Nano based drug delivery systems: recent developments and future prospects. Journal of Nanobiotechnology 16, 71.
Rahim, M.A., Jan, N., Khan, S., Shah, H., Madni, A., Khan, A., Jabar, A., Khan, S., Elhissi, A., Hussain, Z., Aziz, H.C., 2021. Recent advancements in stimuli responsive drug delivery platforms for active and passive cancer targeting. Cancers 13, 670.
Kader, N., 2025. Nanomaterials in Medicine: Advancing Drug Delivery, Diagnostics, and Therapeutics. Journal of Basic and Applied Research in Biomedicine 10, 29-49.
Sarkar, A., Carvalho, E., D'souza, A.A., Banerjee, R., 2019. Liposome-encapsulated fish oil protein-tagged gold nanoparticles for intra-articular therapy in osteoarthritis. Nanomedicine 14, 871-887.
Shep, D., Khanwelkar, C., Gade, P., Karad, S., 2019. Safety and efficacy of curcumin versus diclofenac in knee osteoarthritis: a randomized open-label parallel-arm study. Trials 20, 214.
Shi, J.F., Wu, P., Jiang, Z.H., Wei, X.Y., 2014. Synthesis and tumor cell growth inhibitory activity of biotinylated annonaceous acetogenins. European Journal of Medicinal Chemistry 71, 219-228.
Shilo, M., Berenstein, P., Dreifuss, T., Nash, Y., Goldsmith, G., Kazimirsky, G., Motiei, M., Frenkel, D., Brodie, C., Popovtzer, R., 2015. Insulin-coated gold nanoparticles as a new concept for personalized and adjustable glucose regulation. Nanoscale 7, 20489-20496.
Simos, Y.V., Spyrou, K., Patila, M., Karouta, N., Stamatis, H., Gournis, D., Dounousi, E., Peschos, D., 2021. Trends of nanotechnology in type 2 diabetes mellitus treatment. Asian Journal of Pharmaceutical Sciences 16, 62-76.
Singh, R., Bhateria, R., 2021. Core–shell nanostructures: a simplest two-component system with enhanced properties and multiple applications. Environmental Geochemistry and Health 43, 2459-2482.
Soares, S., Sousa, J., Pais, A., Vitorino, C., 2018. Nanomedicine: principles, properties, and regulatory issues. Frontiers in Chemistry 6, 360.
Lancet, T., 2018. GLOBOCAN 2018: counting the toll of cancer. Lancet (London, England) 392, 985.
Lynch, C., 2020. World Alzheimer Report 2019: Attitudes to dementia, a global survey: Public health: Engaging people in ADRD research. Alzheimer's & Dementia 16, e038255.
Ventola, C.L., 2017. Progress in nanomedicine: approved and investigational nanodrugs. Pharmacy and Therapeutics 42, 742.
Verma, A., Sharma, S., Gupta, P.K., Singh, A., Teja, B.V., Dwivedi, P., Gupta, G.K., Trivedi, R., Mishra, P.R., 2016. Vitamin B12 functionalized layer by layer calcium phosphate nanoparticles: A mucoadhesive and pH responsive carrier for improved oral delivery of insulin. Acta biomaterialia 31, 288-300.
Vinogradov, S., Wei, X., 2012. Cancer stem cells and drug resistance: the potential of nanomedicine. Nanomedicine 7, 597-615.
Xu, P., Chang, J.C., Zhou, X., Wang, W., Bamkole, M., Wong, E., Bettayeb, K., Jiang, L.L., Huang, T., Luo, W., Xu, H., 2021. GSAP regulates lipid homeostasis and mitochondrial function associated with Alzheimer's disease. Journal of Experimental Medicine 218, e20202446.
Yadavalli, T., Shukla, D., 2017. Role of metal and metal oxide nanoparticles as diagnostic and therapeutic tools for highly prevalent viral infections. Nanomedicine: Nanotechnology, Biology and Medicine 13, 219-230.
Herdiana, Y., 2025. New Drug Delivery Systems in Livestock Animals. Indonesian Journal of Pharmaceutics 6, 160-174.
Yetisgin, A.A., Cetinel, S., Zuvin, M., Kosar, A., Kutlu, O., 2020. Therapeutic nanoparticles and their targeted delivery applications. Molecules 25, 2193.
Zielińska, A., Carreiró, F., Oliveira, A.M., Neves, A., Pires, B., Venkatesh, D.N., Durazzo, A., Lucarini, M., Eder, P., Silva, A.M., Santini, A., 2020. Polymeric nanoparticles: production, characterization, toxicology and ecotoxicology. Molecules 25, 3731.