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AN ADVANCED NANOTECHNOLOGY FOR CANCER THERAPY: A REVIEW.

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ABSTRACT

"Nanomedicine is the newest member of molecular nanotechnology branches. It serves for monitoring, repairing, building, and control of biological systems on molecular level, carried out by nanocomponents and nanosystems". The use of nanocarriers as drug delivery systems for chemotherapeutic agents can improve the overall pharmacological properties of commonly used drugs in chemotherapy. The clinical success, as well as the ease with which surface modifications can be made to both liposomes and micelles to accommodate targeting ligands have made these nanocarriers in particular attractive candidates for future work involving targeted drug delivery. Ideally, such carriers should be specifically delivered (targeted) to the pathological area to provide the maximum therapeutic efficacy. Among the many potential targets for such nanocarriers, tumors have been most often investigated. This review attempts to summarize currently available information regarding targeted pharmaceutical nanocarriers for cancer therapy. Certain issues related to some popular pharmaceutical nanocarriers, such as liposomes and polymeric micelles, are addressed, as are different ways to target tumors via specific ligands and via the stimuli sensitivity of the carriers. The importance of intracellular targeting of drug- and DNA-loaded pharmaceutical nanocarriers is specifically discussed, including intracellular delivery with cell-penetrating peptides. Exploiting this new modality of cancer treatment in the coming decade may improve outcomes profoundly with promise of effective treatment response and reducing relapse and metastasis.

KEYWORDS: Nanocarriers, Techniques, Route of administration, Future of Nanocarriers.

INTRODUCTION

"Nanotechnology is expected to have a dramatic impact on medicine. The application of nanotechnology for treatment, diagnosis, monitoring, and control of biological systems is now often referred to as nanomedicine".[1]

Among many possible applications of nanotechnology in medicine, the use of various nanomaterials as pharmaceutical delivery systems for drugs, DNA, and imaging agents has gained increasing attention. Many varieties of nanoparticles are available,[1] such as different polymeric and metal nanoparticles, liposomes, niosomes, solid lipid particles, micelles, quantum dots, dendrimers, microcapsules, cells, cell ghosts, lipoproteins, and different nanoassemblies.

Nanoparticles especially those that are made from biodegradable and biocompatible polymers have been studied as carriers to deliver a wide range of therapeutic molecules including hydrophobic or hydrophilic drugs, proteins and peptides, imaging probes, nucleic acids, and antibodies.[2] They have also been explored to deliver multiple drugs simultaneously. The nanoparticles are able to protect the cargo from the harsh biological conditions until they reach the intended site, enhancing its pharmacokinetics and pharmacodynamics significantly. PEGylated nanoparticles have been shown to evade opsonization by the reticulo-endothelial systems and hence prolong nanoparticle circulation time and reduce accumulation in healthy tissues compared with non-PEGylated nanoparticles. Stimuli-responsive nanoparticulate systems, which respond to external stimuli like temperature, pH and light, have been developed to deliver drugs in a controlled manner. Due to their nanosize, the nanoparticulate delivery systems are able to accumulate in the tumor preferentially due to the enhanced permeability and retention (EPR) effect and more specific targeting can also be achieved with the use of targeting moieties like folate, antibodies and aptamers.[2, 3]

Some days ago, it was found that high-molecular-weight (40 kDa or higher), long-circulating macromolecules as well as various long-circulating nanoparticulate pharmaceutical carriers are capable of spontaneous accumulations in various pathological sites, such as solid tumors and infarcted areas, via the so-called enhanced permeability and retention (EPR) effect.[4]

This effect is based on the fact that pathological vasculature, unlike vasculature of normal healthy tissues, is "leaky" that is, penetrable for large molecules and even for small particles which allows for their extravasation and accumulation in an interstitial tumor space. Such

accumulation is additionally facilitated by the virtual lack of a lymphatic system, responsible for the drainage of macromolecules from normal tissues, in many tumors. It has been found that the effective pore size in the endothelial lining of the blood vessels in most peripheral human tumors ranges from 200 nm to 600 nm in diameter, and the EPR effect allows for passive targeting to tumors based on the cutoff size of the leaky vasculature. We will illustrate here the large family of pharmaceutical nanocarriers with some examples. Among particulate drug carriers, liposomes, micelles, and polymeric nanoparticles are the most extensively studied and possess the most suitable characteristics for encapsulation of many drugs, genes, and diagnostic (imaging) agents. These drug carriers as well as any other pharmaceutical nanocarriers can be surface modified by a variety of different moieties to impart them with certain properties and functionalities.[3]

Among the most popular and well-investigated drug carriers are liposomes (mainly, for the delivery of water- soluble drugs) and micelles (for the delivery of poorly soluble drugs). Liposomes are artificial phospholipid vesicles that vary in size from 50 to 1000 nm and can be loaded with a variety of water-soluble drugs (into their inner aqueous compartment) and sometimes even with water insoluble drugs (into the hydrophobic compartment of the phospholipid bilayer). For more than 2 decades they have been considered to be promising drug carriers.

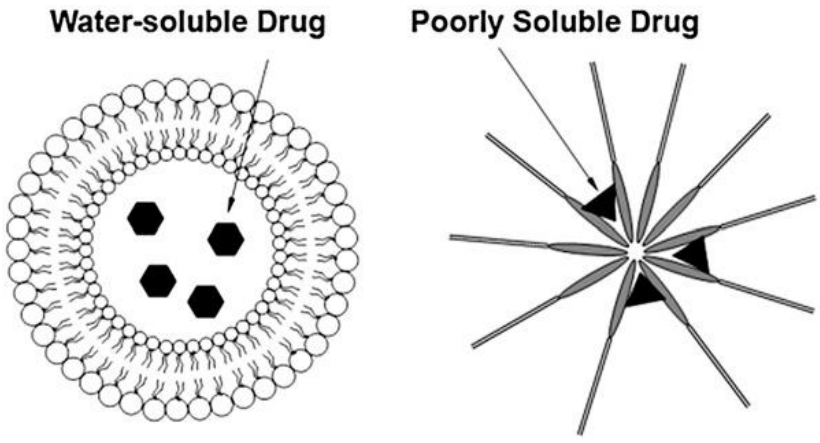

Figure 1. Schematic pictures of the liposome (left) and micelle (right) and their load with various drugs.[4]

FUNCTIONS OF NANOCARRIERS

1) Prolonged circulation in the blood and ability to accumulate in various pathological areas (e.g., solid tumors) via the EPR effect (protective polymeric coating with polyethylene glycol [PEG] is frequently used for this purpose).

2) The ability to specifically recognize and bind target tissues or cells via the surface-attached specifi c ligand (monoclonal antibodies as well as their Fab fragments and some other moieties, eg, folate or transferrin, are used for this purpose).

3) The ability to respond to local stimuli characteristic of the pathological site by, for example, releasing an entrapped drug or specifically acting on cellular membranes under the abnormal pH or temperature in disease sites (this property could be provided by surface-attached pH- or temperature sensitive components).[4,5]

4) The ability to penetrate inside cells bypassing lysosomal degradation for efficient targeting of intracellular drug targets (for this purpose, the surface of nanocarriers is additionally modified by cell-penetrating peptides).

5) They are biologically inert and completely biocompatible, and they cause practically no toxic or antigenic reactions; drugs included in liposomes are protected from the destructive action of external media.

6) The use of targeted liposomes, that is, liposomes selectively accumulating inside an affected organ or tissue, increases the efficacy of the liposomal drug and decreases the loss of liposomes and their contents in the reticuloendothelial system (RES).[5,6]

Table1.Some Examples of Liposomal Drugs Approved for Clinical Application or Undergoing Clinical Evaluation for Cancer Therapy.

Active Drug (and product name for liposomal preparation)	**Indications**
Daunorubicin (DaunoXome)	Kaposi ’ s sarcoma
DNA plasmid encoding HLA-B7 and b 2 microglobulin (Allovectin-7).	Metastatic melanoma
All-trans retinoic acid (Altragen)	Acute promyelocytic leukemia; non-Hodgkin’s lymphoma; renal cell carcinoma; Kaposi’s sarcoma.
Doxorubicin in polyethylene glycol liposomes (Doxil, Calyx)	Refractory Kaposi’s sarcoma; ovarian cancer; recurrent breast cancer.

NANOCARRIERS

99% of chemotherapy drugs do not reach the Cancer cells.

Nanotubes, nanorods, dendrimers, nanospheres, nanoantennas, using carbon, iron, gadolinium, gold, silicon, etc.[6, 7]

Antigen binding peptide ligands are attached to the nanostructures.

Folic acid baiting.

Passive targeting - Leaky blood vessels near tumors cause the nanoparticles to cluster around the tumors.[7]

ADVANTAGES OF NANOCARRIERS

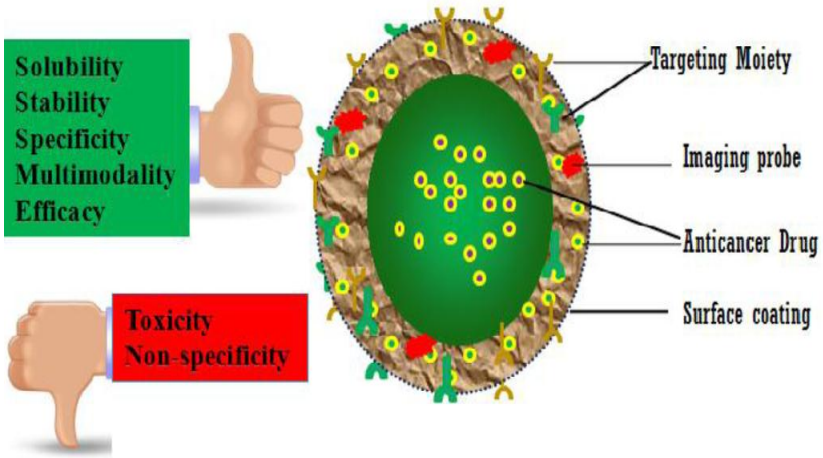

Figure: digramatic representation of advantages of nanocarriers. (http://www.hindawi.com/journals/mi/2012/126463.fig.003.jpg).[11]

1. Protect drugs from being degraded in the body before they reach their target.[7,8]
2. Enhance the absorption of drugs into tumors and into the cancerous cells themselves.
3. Allow for better control over the timing and distribution of drugs to the tissue, making it easier for oncologists to assess how well they work.
4. Prevent drugs from interacting with normal cells, thus avoiding side effects.[8]

CHARACTERISATION OF NANOCARRIERS

1. Nanocarriers range from sizes of diameter 1–100 nm.
2. Because of their small size, nanocarriers can deliver drugs to otherwise inaccessible sites around the body.
3. Since nanocarriers are so small, it is oftentimes difficult to provide large drug doses using them.
4.The emulsion techniques used to make nanocarriers also often result in low drug loading and drug encapsulation, providing a difficulty for the clinical use.[8,9]

TECHNOLOGY OF NANOCARRIERS

Based on nanotechnology, nanocarriers synthesized from organic and inorganic materials have been developed, such as nanoparticles, micelles, carbon nanotubes, dendrimers, quantunm dots, and nanofibers.

They have shown great potential in cancer therapy by enhancing the performance of medicines and reducing systemic side effect in order to gain therapeutic efficiency.[9]

1. Polymeric Nanoparticles

Polymeric nanopaticles are particles of less than 1 m diameter that are prepared from natural or synthetic polymers.[9] Depending on the methods of preparation, nanoparticles can be obtained with different properties and different release characteristics by forming matrix-type or reservoir-type structure, named nanospheres or nanocapsules.[9,10]

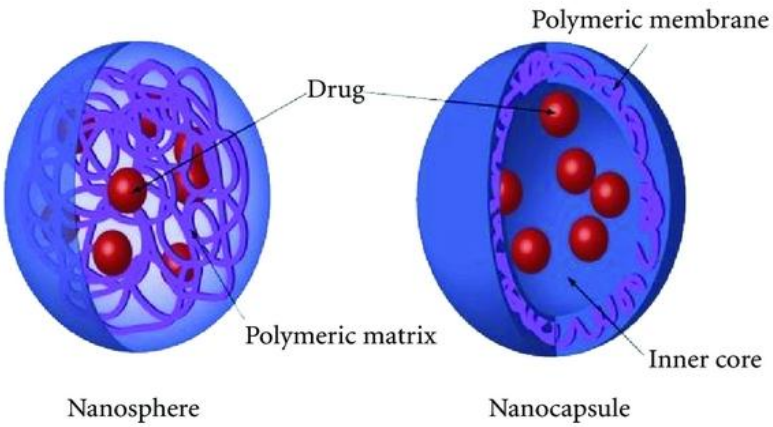

Figure: NanosphereandNanocapsule.
(http://www.hindawi.com/journals/mi/2012/126463.fig.003.jpg)[11]

They have been considered as the promising carriers for drug delivery because they can improve the specificity of action of drugs by changing their tissue distribution and pharmacokinetics.

Polymeric nanoparticles have played pivotal roles in delivering antitumor drugs in a targeted manner to the malignant tumor cells, thereby reducing the systemic toxicity and increasing their therapeutic efficacy.

Due to the reticulo-endothelial system (RES) and the effect of enhanced permeation and retention (EPR), nanoparticles can be formulated for passive delivery to the lymphatic system, brain, arterial walls, lungs, liver, spleen, or made for long-term systemic circulation. The critical feature of polymeric nanoparticles as drug carriers is that they are amenable to surface functionalization for active targeting to tumor tissues or cells and for stimulus-responsive controlled release of drug.[10, 12]

Active targeting of nanoparticles to action sites is based on the pathological state of tumor tissues, such as the angiogenesis and the over expressed receptors. Thus, varieties of researchers have focused on formulating multifunctional nanoparticles to improve the effectiveness of drug delivery and therapy.

When projecting the polymer carrier systems for various types of drugs, the whole series of polymers have been studied, differing in nature and structure.

Some nanosystems suitable for drug delivery are created by hydrophobic association of amphiphilic molecules. For example, the molecules having a certain part strongly hydrophobic and the rest of molecule is strongly hydrophilic, like in the case of micelles and liposomes.[12, 13]

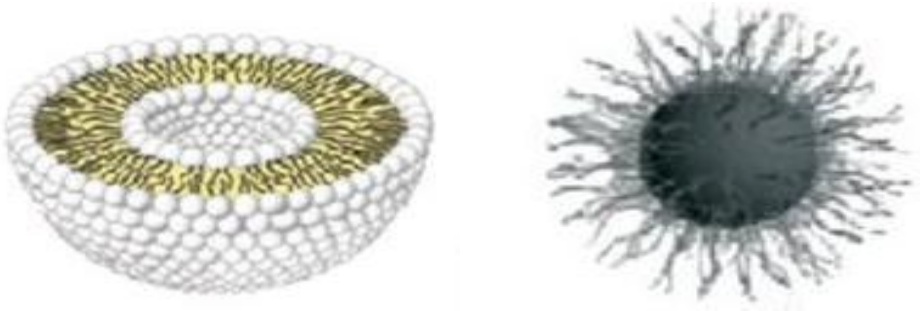

Figure: Liposome and Micelle. (http://www.mdpi.com/2079-4991/2/3/217/htm).[14]

These lipid-based nanoparticles are considered as the least toxic for in vivo applications and significant progress has been made in the area of drug delivery using lipid-based nanoassemblies.

2. Lipid Nanocarriers

Lipid nanocarriers cover a broad scale of various systems, particularly lipid nanocapsules, micelles and liposomes, which can be used for the encapsulation of drugs that selectively target malignant cells.

Lipid nanocapsules are produced through a phase inversion process that follows the formation of an oil/water microemulsion containing an oily fatty phase, a non-ionic hydrophilic surfactant and a lipophilic surfactant. They can be adjusted from 20 to 100 nm with a narrow distribution. They can enter into the intracellular compartment of cancer cells, escape from lysosomes and improve the activity of a number of anticancer hydrophobic compounds.

For example, Weyland et al. developed safe nanocarriers for administration of SV30, which is a new analogue of the pro-apoptotic molecule HA14-1.[14,15]

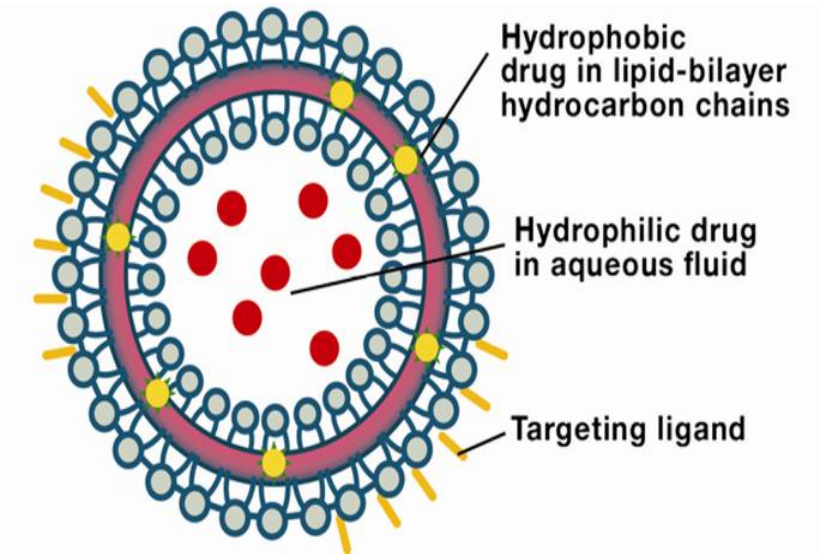

Figure: Lipid Nanocarriers. (http://www.mdpi.com/2079-4991/2/3/217/html)[14]

3. Hydroxyapatite

The investigated chitosan modified hydroxyapatite nanocarriers loaded with celecoxib, which is a potential anticancer drug against most carcinomas, especially in patients with familial adenomatous polyposis and precancerous disease of the colon.

Nanoparticles exhibited small, narrow hydrodynamic size distributions, hemocompatibility, high entrapment efficiencies and sustained release profiles. Similarly, Wang et al. fabricated flower-like nanostructured hydroxyapatite hollow spheres (NHHS) as carriers for the cellular delivery of anticancer drug mitoxantrone.[15,16]

4. Gold Nanoparticles: Recently, gold nanoparticles (AuNPs) have been studied in biological and photothermal therapeutic contexts. This interest is motivated by the capability

of AuNPs to bind a wide range of organic molecules, their low level of toxicity, and strong and tunable optical absorption.

AuNPs can be used as drug and vaccine carriers into target cells or specific tissues. Generally, this has been achieved by modifying the surface of the AuNPs so that they can bind to the specific targeting drugs or other biomolecules.[16]

AuNPs can be directly conjugated with antibiotics or other drug molecules via ionic or covalent bonding or by physical absorption.

The release of a drug from AuNPs could proceed via internal stimuli (operated within a biologically controlled manner, such as pH) or via external stimuli (operated with the support of stimuli-generating processes, such as the application of light).

AuNPs size is generally about 50 nm, which is smaller than other nanomaterials like core/shell nanostructures.

For example: gum Arabic glycoprotein functionalized AuNPs possess optimum sizes (core diameter of 12–18 nm and hydrodynamic diameter of 85 nm) to target individual tumor cells and penetrate through tumor vasculature and pores.

They demonstrated that multidrug resistance in cancer cells can be significantly overcome by a combination of highly efficient cellular entry and a responsive intracellular release of doxorubicin from AuNPs in acidic organelles.[16, 17]

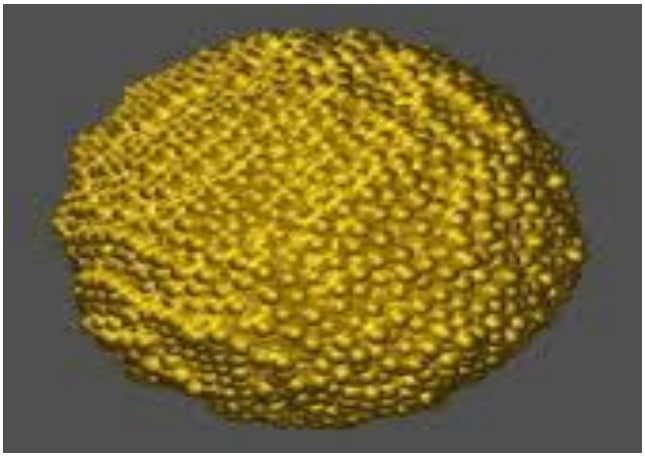

Figure: Gold Nanocarriers. (https://www.google.co.in)[18]

5. Magnetic Nanoparticles

The usage of magnetic nanoparticles (MNPs) made of pure iron oxide in targeted and controlled drug delivery is limited mainly due to their insufficient biocompatibility. Therefore their modification with various materials, e.g. polymers, is unavoidable.

MNPs can be used for targeting in drug and gene delivery in the case of various diseases, including cancer. Magnetic field (represented by a magnet) allows passing MNPs through the cell membrane and reaching the nucleus.[19]

Chemical drug (anticancer drug, e.g. doxorubicin), biological drug (therapeutic specific proteins or peptides), nucleic acids (siRNA, antisenseRNA, DNA) and monoclonal antibodies are anchored on MNPs to increase the selectivity of target drugs to tumor cells.[20]

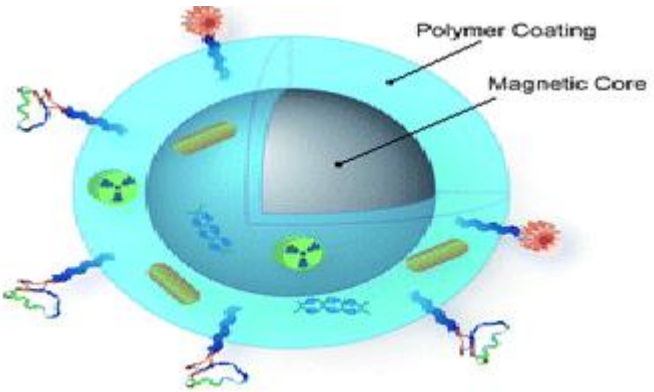

Figure: Magnetic Nanoparticle. (https://www.google.co.in)[18]

Another example of multilayered nanoparticles combining magnetic core and two encompassing polymeric shells. Such nanocomposite can contain both hydrophilic and hydrophobic drugs, the first loaded into PNIPA Am MNPs, while the second (curcumin) embedded in outer PLGA layer conjugated in their study aqueous based protein HER2 (Human Epidermal growth factor Receptor glycerol mono oleate coated MNPs. The obtained results showed enhanced uptake in the human breast carcinoma cell line (MCF-7),which provides another potential use for highly sensitive and selective drug target for cancer HER2 positive breast cancer.[21] Multifunctional and water-soluble SPIO nanocarriers were developed by Yang and colleagues for targeted drug delivery and positron emission tomography/MRI dual-modality imaging of tumors with integrin v3 cell expression. An anticancer drug was conjugated into the PEGylated SPIO nanocarriers via pH-sensitive bonds.[21, 22]

6. Quantum Dots

The preparation of non-cytotoxic quantum dots (QDs) for molecular imaging and targeting therapy has been intensively investigated. QDs were found as an alternative to the organic dyes and fluorescent proteins and thus they can be used for various biosensing purposes.

The photo-physical properties which make QDs interesting as compared to classic organic dyes are

Broad absorption spectra,

Very narrow emission spectra,

Long fluorescence lifetime,

High stability against photo bleaching.[22]

QDs have also high quantum yield, high molar extinction coefficients and large effective Stokes shift. QDs always emit the same wavelength of light no matter what excitation wavelength is used. Therefore, multiple QDs with different emission spectra can be simultaneously visualized using a single excitation light source. The dimension of the core determines the band gap and hence the color of emission. An increase in particle size produces a red shift in the emission spectrum. In principle, the emission of QDs can be coarse-tuned by the choice of the material and later fine-tuned by playing with the size of the core. The basic principles for in vivo targeting and imaging of cancers using QDs are the bio distribution of QD bio conjugates, penetration depths of excitation light and photoluminescence, tissue auto fluorescence, toxicity, and pharmacokinetics. Bioconjugated QDs were applied in vivo either systemically for deep cancers or subcutaneously for marginal cancers.

Yuan et al. prepared monodispersed ZnO QDs with strong blue emission by a chemical hydrolysis method. They described a new approach of combining QDs technology with biodegradable chitosan (N-acetyl glucosamine) for tumor-targeted drug delivery. Chitosan enhanced the stability of the QDs because of the hydrophilicity and cationic charge of chitosan. The encapsulation of QDs by polymers, phospholipids or inorganic shell prevents the dissociation and enables anchoring of biomolecules. Silica-shelled QDs represent probably the most attractive alternative.[22, 23]

7. Silica Nanoparticles

Silica-based nanoparticles also belong to the group of suitable nanocarriers for cancer treatment. They allow the systemic or topical ADMINISTRATION of a photosensitive drug,

so called photosensitize (PS), into the cancer cells. The researchers coated PS filled mesoporous silica nanoparticles with lipid layer to achieve the cell membrane structure and biocompatible surfaces.

Loaded the Fe3O4/SiO2 hollow mesoporous spheres with doxorubicin.

The authors discussed the influence of particle size, mesoporous shell thickness and concentration of Fe3O4/SiO2 hollow mesoporous spheres on cell uptake and on in vitro cytotoxicity to HeLa cells.[23]

ADMINISTRATION ROUTES

The choice of a delivery route is driven by the various facts, such as

i) Patient acceptability.

ii) The properties of the drug (e.g. its solubility).

iii) Access to a disease location.

iv) Effectiveness in dealing with the specific disease.

At present, there are several routes - peroral route, pulmonary delivery, transdermal delivery, parenteral routes including intravenous, intramuscular and subcutaneous, trans-tissue and local delivery systems, and gene delivery systems.[23, 24]

The most important drug delivery route is the peroral one as it offers advantages of convenience and price availability of administration, and potential manufacturing cost savings.

Pulmonary delivery is also important and is realized in a variety of ways - via aerosols, metered dose inhaler systems (MDIs), powders (dry powder inhalers), and solutions (nebulizers); all of them may contain nanostructures such as liposomes, micelles, nanoparticles, and dendrimers.[24]

Aerosol products for pulmonary delivery comprise more than 30 % of the global drug delivery market.

Research into lung delivery is driven by the potential for successful drug delivery, and by the promise of an effective delivery mechanism for gene therapy.

E.g. in cystic fibrosis treatment, as well as the need to replace chlorofluorocarbon propellants in MDIs.

Pulmonary drug delivery offers both local targeting for the treatment of respiratory diseases and increasingly appears to be a viable option for the delivery of drugs systemically.

Transdermal drug delivery avoids problems such as gastrointestinal irritation, metabolism, variations in delivery rates and interference due to the presence of food.

It is also suitable for unconscious patients.

The technique is generally non-invasive and aesthetically acceptable, and can be used to provide local delivery over several days.

Limitations include slow penetration rate, lack of dosage flexibility and/or precision, and a restriction to relatively low dosage drugs. Gene delivery is a challenging task in the treatment of genetic disorders.

In the case of this approach, the plasmid DNA has to be introduced into the target cells, which should get transcribed and the genetic information should ultimately be translated into the corresponding protein.[24, 25]

To achieve this goal, a number of hurdles are to be overcome by the gene delivery system. The transfection is affected by

i) Targeting the delivery system to the target cell.
ii) Transport through the cell membrane.
iii) Uptake and degradation in the endolysosomes.
iv) Intracellular trafficking of plasmid DNA to the nucleus.[25]

FUTURE OF NANOCARRIERS IN CANCER

Nanotechnology is beginning to change the scale and methods of drug delivery. For decades, researchers have been developing new anticancer agents and new formulations for delivering existing and new agents.

The entry of binary and ternary nanoparticles that combine synthetic polymers with proteins or drugs, as well as polymer micelles that incorporate covalently bound drug, into clinical

development, has established polymer therapeutics as an expanding and credible role in cancer therapeutics.

The Food and Drug Administration approval of Abraxane has led to the strong belief that the nanoparticle, protein-bound technology has become a key aspect for the development of anticancer agents.[25, 26]

The simple idea that eliminating cremophor from the taxol formulation and producing a compound that produces no hypersensitivity reactions and obviates the need for premedication has led to this new agent being incorporated into various breast cancer adjuvant trials.

Several binary molecules have been formulated and some of their pitfalls have led to the development of even more sophisticated "ternary biomolecules" that incorporate a complex understanding of chemistry, biology, and medicine.

For specific targeting, the differences between cancerous cells and normal cells, which include uncontrolled proliferation, insensitivity to negative growth regulation and antigrowth signals, angiogenesis, and metastasis can be exploited.

There is a growing body of knowledge of unique cancer markers thanks to recent advances in proteomics and genomics.

They form the basis of complex interactions between bioconjugated nanoparticles and cancer cells. Carrier design and targeting strategies may vary according to the type, developmental stage, and location of the cancer.[26, 27]

RECENT APPLICATIONS

Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors: information technology, energy, environmental science, medicine, homeland security, food safety, and transportation, among many others. Described below is a sampling of the rapidly growing list of benefits and applications of nanotechnology.

Nanoscale additives in polymer composite materials for baseball bats, tennis rackets, motorcycle helmets, automobile bumpers, luggage, and power tool housings can make them simultaneously lightweight, stiff, durable, and resilient.

Nanoscale additives to or surface treatments of fabrics help them resist wrinkling, staining, and bacterial growth, and provide lightweight ballistic energy deflection in personal body armor.[27]

Nanoscale thin films on eyeglasses, computer and camera displays, windows, and other surfaces can make them water-repellent, antireflective, self-cleaning, resistant to ultraviolet or infrared light, antifog, antimicrobial, scratch-resistant, or electrically conductive.

Nanoscale materials in cosmetic products provide greater clarity or coverage; cleansing; absorption; personalization; and antioxidant, anti-microbial, and other health properties in sunscreens, cleansers, complexion treatments, creams and lotions, shampoos, and specialized makeup.

Nano-engineered materials in the food industry include nanocomposites in food containers to minimize carbon dioxide leakage out of carbonated beverages, or reduce oxygen inflow, moisture outflow, or the growth of bacteria in order to keep food fresher and safer, longer. Nanosensors built into plastic packaging can warn against spoiled food.

Nanosensors are being developed to detect salmonella, pesticides, and other contaminates on food before packaging and distribution.

Nano-engineered materials make superior household products such as degreasers and stain removers; environmental sensors, alert systems, air purifiers and filters; antibacterial cleansers; and specialized paints and sealing products.[27, 28]

FUTURE TRANSPORTATION APPLICATION

Nano-engineering of steel, concrete, asphalt, and other cementitious materials, and their recycled forms, offers great promise in terms of improving the performance, resiliency, and longevity of highway and transportation infrastructure components while reducing their cost. New systems may incorporate innovative capabilities into traditional infrastructure materials, such as the ability to generate or transmit energy.

Nanoscale sensors and devices may provide cost-effective continuous structural monitoring of the condition and performance of bridges, tunnels, rails, parking structures and pavements over time.

Nanoscale sensors and devices may also support an enhanced transportation infrastructure that can communicate with vehicle-based systems to help drivers maintain lane position, avoid collisions, adjust travel routes to circumnavigate congestion, and other such activities.[27,28,29]

MEDICAL AND HEALTH APPLICATION

Quantum dots are semiconducting nanocrystals that can enhance biological imaging for medical diagnostics. When illuminated with ultraviolet light, they emit a wide spectrum of bright colors that can be used to locate and identify specific kinds of cells and biological activities. These crystals offer optical detection up to 1,000 times better than conventional dyes used in many biological tests, such as MRIs, and render significantly more information.

Nanotechnology has been used in the early diagnosis of atherosclerosis, or the buildup of plaque in arteries. Researchers have developed an imaging technology to measure the amount of an antibody-nanoparticle complex that accumulates specifically in plaque.[28]

ENVIRONMENTAL APPLICATION

Nanotechnology could help meet the need for affordable, clean drinking water through rapid, low-cost detection of impurities in and filtration and purification of water. For example, researchers have discovered unexpected magnetic interactions between ultra small specks of rust, which can help remove arsenic or carbon tetrachloride from water (see image); they are developing nanostructured filters that can remove virus cells from water; and they are investigating a deionization method using nano-sized fiber electrodes to reduce the cost and energy requirements of removing salts from water.[28, 29]

Nanoparticles will someday be used to clean industrial water pollutants in ground water through chemical reactions that render them harmless, at much lower cost than methods that require pumping the water out of the ground for treatment.

Researchers have developed a nanofabric "paper towel," woven from tiny wires of potassium manganese oxide that can absorb 20 times its weight in oil for cleanup applications.[29]

SUSTAINABLE ENERGY APPLICATIONS

Nanotechnology is improving the efficiency of fuel production from normal and low-grade raw petroleum materials through better catalysis, as well as fuel consumption efficiency in vehicles and power plants through higher-efficiency combustion and decreased friction.

Nano-bioengineering of enzymes is aiming to enable conversion of cellulose into ethanol for fuel, from wood chips, corn stalks, unfertilized perennial grasses, etc.[29,30]

Nanotechnology is already being used in numerous new kinds of batteries that are less flammable, quicker-charging, more efficient, lighter weight, and those have a higher power density and hold electrical charge longer. One new lithium-ion battery type uses a common, nontoxic virus in an environmentally benign production process.[30]

CONCLUSION

This review was concluded that, applications in very distinct areas of human research including both industrial and scientific branches. It is clear that medicinal applications are also included.

Also has summarized the applications of various nanosizing strategies to carry drugs to the place of need. Since nanotechnology and nanomedicine are anticipated to be major drivers of personalized medicine, it is essential to focus the power of these technologies to enable personalized medicine through carrying the drugs. Another challenge associated with this type of delivery is the release of the drug from the nanocarrier for cancer treatment.

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