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A REVIEW ON CANCER TREATMENT USING NANO MATERIALS

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ABSTRACT :

Nano materials were found to have a significant role on cancer therapy. These systems collaborate engineered cells with nano scale carriers to promote the targeted transport and controlled release there by enhancing the therapeutic efficacy and minimizing toxicity. Various nano materials, including liposomes, polymeric nano particles, metal based nano structures are used nowadays, because of their ability to enhance drug stability, prolong circulation time and facilitate tumor specific accumulations. This review provides a comprehensive analysis of the role of nano materials in cell mediated drug delivery for the treatment of cancer along with their mechanism, advantages and limitations. The future prospects in clinical applications are also examined.

Keywords: cell, drug delivery, cancer treatment, nanomaterial, liposome, engineered cells

INTRODUCTION :

Cancer is still the world's largest cause of death and is a severe, incurable, and aggressive disease. Existing cancer therapies includes chemotherapy, immunotherapy, radiotherapy, gene therapy and surgical procedures. Chemotherapy is the main treatment for cancer. Intravenous administration of chemotherapeutic drugs will cause harmful effects to human body this is because of their short half-life and the lack of targeting ability. To address these challenges, cell-based drug delivery system has emerged as a promising approach, utilizing engineered cells to transport and release therapeutic agents in a targeted manner.

With the help of nanotechnology, nano-medicine has shown a good application prospect in improving cancer treatment. When compared with individual drug delivery, nano-delivery system can prolong drug half-life to reduce side effects and improve drug accumulation in tumor through passive or active targeting, which has greater advantage in cancer therapy. Drug delivery methods based on nanoparticles have demonstrated numerous benefits in the treatment of cancer, including improved pharmacokinetics, accurate tumor cell targeting, less side effects, and decreased drug resistance. Compared with normal tissues the tumor tissues have abundant blood vessels, irregular blood vessel wall cells, and nanoparticles are easy to ooze from tumor blood vessels. Usually nanoparticles, bacteria and viruses are utilized as delivery vehicles to promote drug stability and transport the drug to the desired site. Nowadays nano particles-based therapy has been reported to how potential in overcoming multi drug resistance in several type of cancers including breast cancer ovarian cancer and prostate cancer. Nano technology in medicine has opened a new stage of cancer treatment and the combination of these two fields deserves more in-depth research.

This review outlines the role of nanomaterials in cell-based drug delivery system for cancer therapy. It discusses various types of nano material, their mechanism of action, advantages and limitations. Furthermore, it highlights the recent advancements in this field along with future perspectives.

NANOPARTICLES IN CANCER THERAPY :

Nanoparticles are used in cancer treatment to deliver drugs directly to tumors, which can improve the efficacy of treatment and reduce side effects. The nanoparticles used in medical treatments are characterized by their sizes, shapes, and surface charge. Nanoparticle with a diameter range of 10 to 100 nm is generally considered suitable for cancer therapy. The desired size can effectively deliver drugs and achieve enhanced permeability and retention (EPR) effect. Nanoparticles are found to have deep tissue penetration to increase permeability and retention effect. Apart from that, the surface characteristics of nanoparticles improve the bioavailability and half-life.

Different types of nanoparticles used for cancer therapy are as follows: - organic nanoparticles, inorganic nanoparticles and hybrid nanoparticles. Organic nanoparticles include: - liposome-based nanoparticles, polymer-based nanoparticles and dendrimers. Gold nanoparticles, carbon nanotubes, silica nanoparticles, magnetic nanoparticles and quantum dots make up inorganic nanoparticles.

Hybrid nanoparticles include: - lipid polymer hybrid nanoparticles, organic-inorganic hybrid nanoparticles, and cell membrane-coated nanoparticles.

ORGANIC NANOPARTICLES :

Organic nanoparticles are small particles made of polymers or aggregated molecules. Liposome is an example for organic nanoparticles. It comprises of an external lipid layer and a center entangling either hydrophobic or hydrophilic medicate. With respect to cancer treatment, liposomes give a great stage for in vivo conveyance of numerous anti-tumor drugs, such as doxorubicin and paclitaxel. In the field of breast and prostate cancer, the application of liposomes has been progressively common. Different paclitaxel liposomes have been illustrated to have higher anti-tumor effectiveness and high bioavailability compared to free paclitaxel. Liposomal doxorubicin has been demonstrated to diminish cardiotoxicity and is also effective in the treatment of breast cancer.

Polymer-based nanoparticles are another type of organic nanoparticle. Polylactic-co-glycolic acid (PLGA), a common polymeric nanoparticle, envelops co-polymerization of glycolic acid and lactic acid. PLGA is broadly utilized as a drug carrier because of its superior biocompatibility, biodegradation and EPR impact. Dendrimers, another organic nanoparticle is widely used in the treatment of cancer. They are flexible and biocompatible macromolecules that are characterized by a three-dimensional structure. The hydrophobic center empowers the insoluble anticancer drugs to be ingested and conveyed easily, whereas the hydrophilic section increments solidness, in this way dendrimers decrease the take-up of drug by the reticuloendothelial framework and decreasing their time period in circulation.

INORGANIC NANOPARTICLES :

Inorganic nanoparticles are non-toxic, hydrophilic, and biocompatible with living system. They are also more stable than organic nanoparticles. They have a wide variety of application. Some of the inorganic nanoparticles are gold nanoparticles, carbon nanotubes, quantum dots and silica nanoparticles. Gold nanoparticles are the most widely used inorganic nanoparticles. The gold center is inactive and non-toxic, and surface-functionalized AuNPs have been demonstrated to improve drug bioavailability in tumor centers. Gold nanoparticles are included in multimodal cancer treatment like gene therapy, photothermal treatment and immunotherapy. Carbon nanotubes are widely used in cancer treatment due to their special organic, physical, and chemical properties. They have been utilized to convey anticancer drugs like doxorubicin, paclitaxel, and methotrexate. When carbon nanotubes are exposed to infrared radiation heat is produced which could be used for thermal ablation in cancer therapy. Mesoporous silica nanoparticle is suitable for drug delivery. Due to superior pharmacokinetics and treatment viability, as well as high stability silica nanoparticles are considered one of the best vehicles for drug delivery. In addition, permeable silicon NPs have appeared extraordinary potential in immunotherapy. The immunoadjuvant properties incorporate advancement of antigen cross presentation, polarization of lymphocytes and discharge of interferon.

Magnetic nanoparticles utilized for medicate conveyance does not contain metal or metal oxide nanoparticles. Magnetic nanoparticles are commonly coated with natural materials like polymers and fatty acids. These particles shows high efficiency in anticancer therapy.

HYBRID NANOPARTICLES :

These are the combination of organic and inorganic nanoparticles. Lipid-polymer hybrid nanoparticles consisting of an inner polymeric center and lipid shell offers a promising drug delivery in the treatment of different types of cancer like pancreatic cancer, breast cancer, and metastatic prostate cancer.

The combination of organic and inorganic nano-materials is a common strategy of nanoparticle design. For illustration, a liposome-silica hybrid (LSH) nanoparticle comprises of a silica center and an encompassing lipid bilayer and has been synthesized and appeared to be substantial in conveying drugs to destroy prostate and breast cancer cells.

Cell film coating nanotechnology is developing and has progressively picked up more consideration. This innovation tends to give the nanoparticles with biological characteristics straightforwardly by coating nanoparticles with natural cell layer. The coatings incorporate cell films obtained from leukocytes, red blood cells, platelets, cancer cells. So also, a few considers have utilized cancer cell membrane-cloaked mesoporous silica nanoparticles for cancer treatment, which moves forward the soundness and focusing on capacity of nano-carriers. Additionally, the advancement of dual-membrane coated nanoparticles can upgrade the work of nanoparticles. For occurrence, erythrocyte-platelet crossover and erythrocyte-cancer crossover membrane-coated nanoparticles were demonstrated to display way better soundness and longer circulation life.

MECHANISM OF TARGETING :

Targeting of cells is important to protect normal cells in case of cancer treatment. The targeting mechanisms can be broadly separated into two categories, passive targeting and active targeting.

PASSIVE TARGETING

In passive targeting, the drugs are effectively conveyed to the target location for the curative action. Rapid multiplication of cancer cells actuates neovascularization. The fast and flawed angiogenesis causes nanoparticles to spill from blood vessels and accumulate within the tumor tissue. This leads to EPR impact, one of the driving powers of passive targeting. The size of the nanoparticles has a huge impact on EPR effect. On the other hand, bigger particles are more likely to be cleared by the resistant framework. In expansion to the EPR impact, the tumor microenvironment is moreover a vital figure in the passive delivery of nanomedicines. Glycolysis is one of the metabolic characteristics of cancer cells and is the fundamental source of vitality for cancer cell expansion. Glycolysis yields an acidic environment and decreases the pH of the tumor microenvironment. Some pH-sensitive nanoparticles are activated by the low pH level and are able to discharge drugs inside the region of cancer cells. Some of the limitations of passive targeting includes non-specific drug conveyance, non-universal presence of the EPR impact and distinctive permeability of blood vessels over different tumors.

ACTIVE TARGETING

Active targeting particularly targets cancer cells by the use of ligands and receptors. The ligands on the surface of nanoparticles are chosen to target the particles that are overexpressed on the surface of cancer cells, which permits them to recognize cancerous cells from healthy cells. The interaction between ligands on nanoparticles and the receptors on the surface of cancer cells actuates receptor-mediated endocytosis, which permits the nanoparticles to release drugs. Active targeting is mainly useful for drugs such as proteins and siRNAs. Monoclonal antibodies, peptides, amino acids, vitamins, and carbohydrates act as targeting moieties. These ligands particularly tie to receptors on targeted cells.

TARGETING TO CANCER CELLS

Transferrin, a serum glycoprotein, transfers iron into cells. Transferrin receptors are overexpressed in most tumor cells and are present at low levels in ordinary cells. Hence, transferrin-conjugated nanoparticles are utilized as an active targeting strategy to convey drugs for cancer treatment. Compared to unmodified nanoparticles, transferrin-modified nanoparticles have been appeared to show higher cellular take-up productivity and improved intracellular conveyance of drugs. Transferrin-conjugated polymeric nanoparticles play a critical part in overcoming drug-resistant chemotherapy. Cancer cells express different sorts of glycoproteins, including lectins, that can bind with certain carbohydrates. Targeting cancer cell-surface carbohydrates by lectins conjugated to nanoparticles constitutes the direct lectin targeting pathway, whereas targeting lectins on cancer cells utilizing carbohydrates moieties that are consolidated into nanoparticles constitutes the reverse lectin targeting pathway. Epidermal growth factor receptor which is a part of tyrosine kinase receptors is overexpressed in certain cancers. Targeting human epidermal receptor is a common treatment for positive breast and gastric cancer.

TARGETING TO ENDOTHELIUM

A few nanoparticles do not specifically target cancer cells but have an impact on angiogenesis, which is another strategy of cancer treatment. The interaction between vascular endothelial growth factor (VEGF) and VEGF receptors (VEGFRs) plays a basic part in vascularization. Focusing on VEGFR-2 and VEGFR-3, two major VEGF receptors, at the same time by liposomes has been appeared to improve the treatment efficacy. Integrins are cell surface receptors for extracellular framework proteins that play a critical part in tumor cell movement. The αvβ3 integrin is found high in tumor neovascular endothelial cells, than the resting endothelial and typical cells. αvβ3 integrin is related with VEGFR-2 signalling, and blocking αvβ3 integrin-binding can lead to a lessening in VEGF signalling, showing that focusing on αvβ3 integrin can upgrade the adequacy of anti-VEGFR treatment. Vascular cell adhesion molecule-1 (VCAM-1) is an immunoglobulin-like glycoprotein that is found on the surface of the tumor endothelium and is included in angiogenesis by connection with vascular endothelial cells. Overexpression of VCAM-1 can be seen in different cancers, demonstrating its potential part in the dynamic focusing on nanoparticles for medicate conveyance. Moreover, network metalloproteinase (MMP), a component of the tumor microenvironment, is locked in extracellular framework remodelling and tumor neovascularization. MMP-sensitive NPs have been detailed to play a potential antitumor impact in a few sorts of cancers, including breast cancer, pancreatic cancer, and melanoma.

MECHANISM OF NANOPARTICLES IN OVERCOMING DRUG RESISTANCE

Drug resistance is still a major issue in cancer treatment, in spite of the truth that strategies of cancer treatment are expanding. Multidrug resistance leads to a disappointment of different sorts of cancer medicines. The components of tumor drug resistance incorporate cellular and physiological components, such as overexpression of ATP binding cassette (ABC) transporters (e.g., efflux transporter), inadequate apoptotic machineries, interstitial liquid weight, and acidic and hypoxic tumor microenvironment. Nanomaterials in cell-based drug delivery systems plays an important role in overcoming drug resistance.

THE ROLE OF NANOPARTICLES IN CANCER IMMUNOTHERAPY

The advancement of immunotherapy has brought cancer treatment into a new period. Cancer immunotherapy is basically accomplished by actuating the anti-tumor immune response. Nanoparticles associated immunotherapy incorporates nanovaccines, artificial antigen-presenting cells (aAPCs), and focusing on the immunosuppressed tumor microenvironment (TME).

Nanovaccines provide tumor-associated antigens (TAAs) and adjuvants to APCs, such as dendritic cells (DCs). Nanoparticles, such as liposomes, gold nanoparticles, PLGA nanoparticles, micelles, and dendrimers all have the capability of cytoplasmic conveyance of TAAs into DCs, in this way improving the resistant reaction against tumor cells. Among distinctive sorts of nanoparticles, inorganic nanoparticles such as mesoporous silica and polymers such as acetylated dextran (AcDEX) have been appeared to work as an adjuvant in immunotherapy, driving to an incitement of the safe reaction.

The combination of chemotherapy and immunotherapy is a promising methodology of cancer treatment. Elective approaches of combined chemo-immunotherapy incorporate co-delivery of chemotherapeutics and monoclonal antibodies into permeable silicon nanoparticles, which have been viable in improving complement activation, antibody-dependent cell cytotoxicity (ADCC), and resistant reaction against cancer cells.

CONCLUSION AND FUTURE PERSPECTIVES :

An advancement in cancer treatment has been brought by the invention of nanotechnology. Various types of nanoparticles including natural and inorganic nanoparticles is now been broadly utilized in the clinical treatment of cancer. Compared to conventional drugs, nanoparticle-based drug delivery system

has improved the efficacy of treatment and decreased several side effects. The use of nanoparticles in combination with other therapies such as immunotherapy and photodynamic therapy has also shown promising results.

while significant progress has been made there are still challenges to be addressed such as toxicity, biocompatibility and scalability. However ongoing research and advancements in nanotechnology are expected to overcome these challenges and lead to the development of more effective and targeted cancer therapies. Development of novel nanomaterials and formulations along with the investigation of combination therapy is required in the field of cancer treatment.

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