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A Review on Liver Carcinoma and Nanotechnology Based-drug repurposing

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Abstract:- Hepatocellular carcinoma (HCC) is a complex disease that involves a series of molecular and cellular changes leading to cancer development. Advances in next-generation sequencing technology have enabled the systematic evaluation of molecular landscapes in HCC, highlighting the critical role of cancer metabolism and tumour microenvironment in promoting cancer progression.The development of new and innovative approaches to treat hepatocellular carcinoma (HCC) is urgently needed. The rapidly evolving field of nanotechnology provides endless opportunities for designing materials with unique properties due to their small size and large surface area. Nanotechnology has enabled the design of drug delivery systems that can serve multiple purposes, including treatment, diagnostics, and imaging.

This review provides an update on the potential of cancer nanotechnology and highlights recent advances in therapeutic nanomaterials specifically targeting HCC. We will also discuss the challenges and obstacles that currently hinder the further development of nanomaterials for cancer therapy. The use of nanomaterials in cancer therapy offers tremendous potential for improving treatment efficacy and reducing side effects.

Keyword: *- Microenvironment, Nanomaterials, Hepatocellular Carcinoma, Nanotechnology.*

I. INTRODUCTION:

Liver cancer also known as hepatic cancer Primary hepatic malignancy is cancer that starts in the liver. Liver cancer can be primary starts in the liver or secondary cancer which has spread from elsewhere to the liver, known as liver metastasis. Liver cancer is one of the most common cancers worldwide and it's also one of the most arduous cancers to treat resulting in almost one million death per year, and the danger of this cancer is compounded when the tumour is nonresectable.

Hepatic fibrosis, microbial infections, and hepatocellular, carcinoma are the major sources of hepatic diseases causing significant mortality worldwide; their dissemination is rising despite the availability of standard medication and/ or vaccination.

Utmost drawbacks of standard therapy arise from the inability to deliver sufficient concentration of therapeutics to the liver disease and/or dole to undesirable effects. Because there is no visible symptom or specificity at early stage, most liver cancer patients might reach mid-term or advanced stage when they find something is wrong.

The liver cancer is third leading cause of cancer death, in 2020 an estimated 830,180 people around the world died from the disease. Liver cancer is the 6th most common cancer worldwide. It is 5th most common cancer in the men and the 9th most common cancer in the women. Due to new- life style related factor, such as metabolic syndrome and non-alcoholic fatty liver disease *(Llovet, et.al,2021*) (*Kim, et.al, 2020*) The nominal five-year survival rate of liver cancer or hepatocellular carcinoma (HCC) is only 18% making it one of the most lethal cancers (*Ferrante et.al,2020).*

Nanotechnology &

Nanotechnology has been developed and elevated for tumour diagnosis and treatment, such as nano-intravenous injections for malignant perivascular epithelioid cell tumours.

In a radiological imaging, magnetic resonance imaging (MRI), fluorescence imagining (FMI) and multimodality imaging.

For diagnostic applications in Hepatocellular Carcinoma (HCC) serum makers.

As embolic agents in trans arterial chemoembolization (TACE) or directly drugs.

For application in photothermal therapy and photodynamic therapy. As carriers of chemotherapeutic drugs targeted drugs, and natural plant drugs.

For application in gene and immunotherapy, accord with traditional methods for diagnosis and treatment of HCC, nanoparticles have high sensitivity.

Detract drug toxicity and have a long duration of expedition and can also be assorted with photothermal and photodynamic multimodal combination therapy.

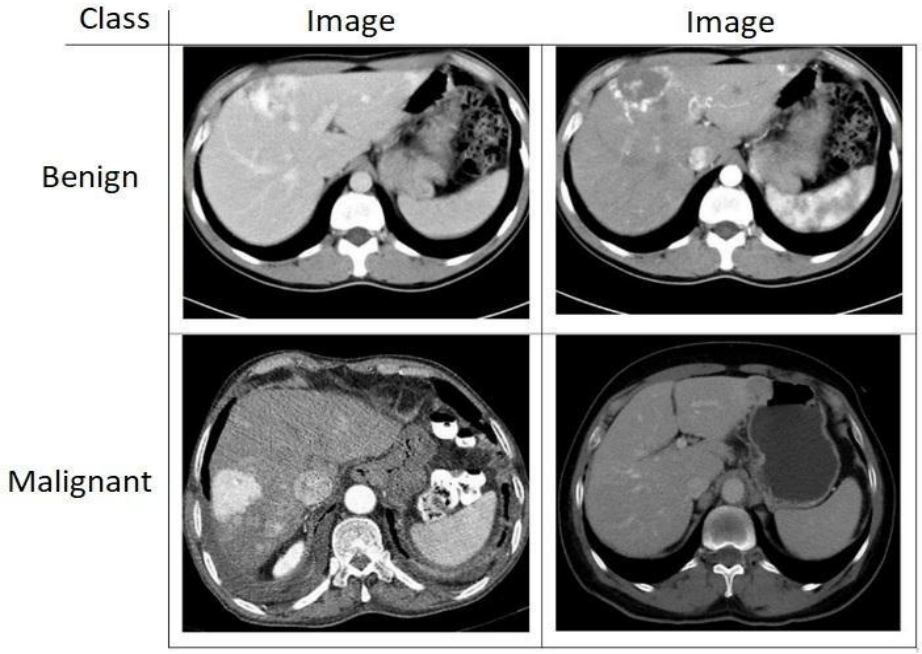

Fig.no.1 CT Scan of Benign & Malignant Liver Carcinoma.

1.1 Etiology of liver cancer

Liver cancer, also known as hepatocellular carcinoma (HCC), can have multiple etiologies.

Some of the common risk factor and causes of liver cancer include.

i. **Chronic viral infections**: chronic infection with hepatitis B or C virus (HBV, HCV) is utmost significant risk factor for liver cancer. These types of viruses can cause liver inflammation and cirrhosis, which increase the risk of developing liver cancer.

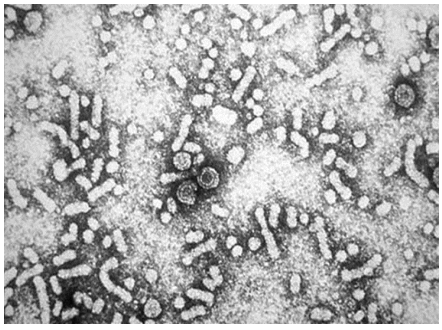

Fig. no 2. HBV, HCV, viruses.

ii. **Alcohol consumption**: - Heavy and long-term alcohol consumption can lead to liver damage and increase the risk factor of liver cancer. The risk is even surpassing in people with liver disease or hepatitis virus infections.

iii. **Non-alcoholic fatty liver disease (NAFLD): - NAFLD** is a condition in which fat accumulates in the liver. It is becoming more common due to the increasing prevalence of obesity and metabolic syndrome. NAFLD can lead to liver inflammation, cirrhosis, and

ultimately, liver cancer.

iv. **Genetic factors: -** Certain genetic mutations can increase the risk of developing liver cancer. As per example, hereditary hemochromatosis, a condition that causes the body to absorb too much iron, can increase the peril of the liver cancer.

v. **Exposure to aflatoxins**: - Aflatoxins are toxins produced by a type of mold that grows on a peanut, corn, and other grains. Eating foods contaminated with aflatoxins can increase the risk of liver cancer.

vi. **Exposure to toxins**: - Exposure to certain chemicals, such as vinyl chloride and arsenic, can cause distress of the liver cancer.

vii. **Diabetes: -** people with diabetes are at higher risk of developing liver cancer, possibly due to the association between diabetes and NAFLD.

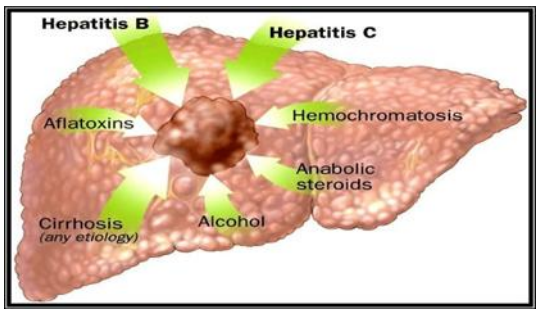

Fig.no.3 Factors Affecting Liver Cancer**.**

It is vital to note that various cases of liver cancer occur in people with no identifiable risk factor. Accordingly regular screening is recommended for individuals at high risk of developing liver cancer.

1.2. CLASSIFICATION OF LIVER CARCINOMA:

Liver cancer can spread from liver parenchyma inclusive of other structure within the liver such as the bile duct, blood vessels or immune cells, in that place there are many sub-types of liver cancer, the most common types.

1.2.1 Hepatocellular carcinoma

The exceedingly frequent liver cancer, accounting for approximately 75% of all primary cancer, that is hepatocellular carcinoma (HCC). HCC is a cancer formed by liver cells, known as hepatocytes, that become malignant. On worldwide level HCC is presume the 3rd most common cause of cancer mortalities. Chronic liver disease, cirrhosis patient had risk of diagnosed with HCC, they should receive screening ultrasounds**.**

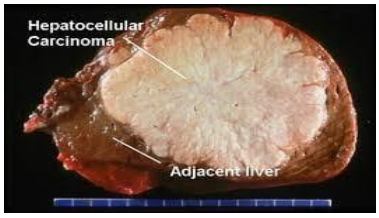

Fig. no.4 Hepatocellular Carcinoma infected reason.

HCC is the most common primary liver malignancy, accounting for 85–90% of primary liver cancers. It has an aggressive clinical course with frequent recurrence (15–90%) and metastasis. (Pei YF, Zhang T, Renault V. et.al,2009;41).

This type of tumour has special characteristics that allow the improvement of diagnostic and treatment techniques used in clinical practice, by combining nanotechnology. The incidence of HCC is on the rise in Europe and the USA, due to new lifestyle-related risk factor, such as metabolic syndrome and the non-alcoholic fatty liver disease (M.L. Cuestas, J.R. Oubina, et.al., 2015). Treatment methods for HCC include resection surgery, liver transplantation, chemotherapy, radiofrequency ablation (RFA), or transarterial chemoembolization (TACE). (Ferrante, N.; Pillai, et.al.,2020).

The unique properties of nanotechnology and functionalities are due in part to their size (between 1and 100nm), and among them are increased biocompatibility, ability to detect early HCC.. (Wu, H; Wang, M., -D.; Liang, et.al.,2021).

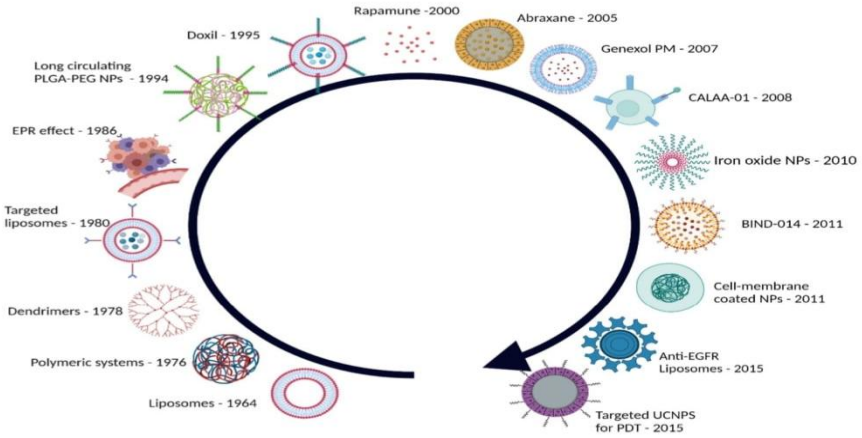

Fig.no.5 Nanotechnologys, Nanomaterials

1.2.2 Intrahepatic cholangiocarcinoma (ICC): This type of cancer starts in the cells that line the bile ducts within the liver. It is less common than HCC and can also be caused by liver fluke infections or other chronic liver diseases. Cancer of the bile duct (cholangiocarcinoma and cholangiocellular cystadenocarcinoma) account for approximately 6% of primary liver cancer. (Ahmed *et.al.*, 2009) Intrahepatic cholangiocarcinoma (CCA) is an epithelial cancer of the intra-

hepatic biliary tree branches. (Dooley JS, Lok AS, Garcia-Tsao G, et.al., 2018 June.)

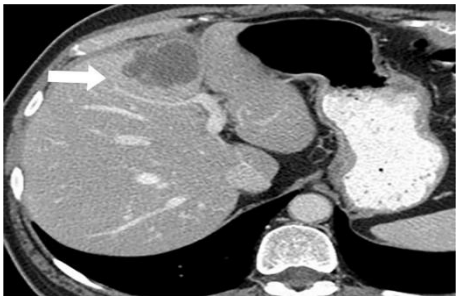

Fig.no.6 Intrahepatic cholangiocarcinoma affected area.

1.4.3 Angiosarcoma and hemangiosarcoma: These are rare types of liver cancer that develop from blood vessels in the liver. They are often more aggressive than other types of liver cancer. Which arerare and rapidly fatal cancer arising from endothelial that line the blood vessels of the liver.

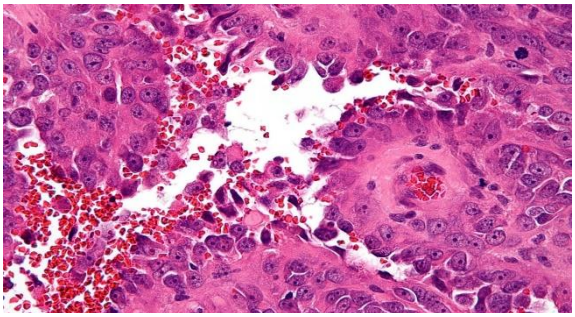

Fig.no.7 Angiosarcoma & Hemangiosarcoma.

2. NANOTECNOLOGY & ITSAPPLICATIONS: -

Nanotechnology holds promise for the treatment of liver carcinoma, also known as liver cancer. Here are some nanotechnology-based approaches being explored for the treatment of liver carcinoma:

1. **Targeted Drug Delivery**: Nanoparticles can be engineered to deliver anticancer drugs specifically to liver cancer cells. By functionalizing the nanoparticles with ligands that recognize liver cancer cells, they can selectively accumulate in the tumor site. This targeted drug delivery approach improves drug efficacy and reduces systemic side

effects. Nanoparticles can also be designed to release drugs in a controlled manner, allowing sustained drug release over time.

2. **Photothermal Therapy:** Certain nanoparticles possess unique properties that can convert absorbed light energy into heat, leading to localized tumor destruction. For example, gold nanoparticles can absorb near-infrared light, which is harmless to normal tissues, but can generate heat to selectively kill cancer cells when irradiated. Photothermal therapy using nanoparticles shows promise in treating liver carcinoma while minimizing damage to healthy liver tissue.

3. **Radiotherapy Enhancement**: Nanoparticles can be utilized to enhance the efficacy of radiotherapy, a common treatment for liver cancer. Metal-based nanoparticles, such as gold or gadolinium nanoparticles, can be employed as radiosensitizers. These nanoparticles accumulate in the tumor and enhance the radiation dose delivered to cancer cells, leading to improved therapeutic outcomes.

4. **Gene Therapy**: Nanoparticles can be used as carriers to deliver therapeutic genes directly to liver cancer cells. This approach, known as gene therapy, aims to inhibit tumor growth, induce cancer cell death, or enhance the body's immune response against the cancer. Nanoparticles can protect the therapeutic genes from degradation and help in their targeted delivery to the tumor site.

5. **Immunotherapy**: Nanoparticles can be engineered to enhance the effectiveness of immunotherapy, which involves stimulating the body's immune system to target and destroy cancer cells. Nanoparticles can serve as carriers for immune-stimulating molecules or antigens, improving their delivery to immune cells and enhancing the immune response against liver cancer cells.

It is important to note that while these nanotechnology-based approaches show promise, they are still in the early stages of research and development. Further studies and clinical trials are needed to evaluate their safety, efficacy, and long-term effects in the treatment of liver carcinoma. Nonetheless, nanotechnology has the potential to revolutionize the treatment landscape for liver cancer, offering targeted and personalized therapeutic options with reduced side effects.

DIAGNOSIS LIVER CARCINOMA VIA NANOTECHNOLOGY:-

Nanotechnology has the potential to revolutionize the diagnosis of liver carcinoma by enabling highly sensitive and specific detection methods. Here are some nanotechnology-based approaches that have been explored for the diagnosis of liver carcinoma:

1. **Nanoparticle-based imaging**: Nanoparticles can be engineered to serve as contrast agents for various imaging techniques, including magnetic resonance imaging (MRI), computed tomography (CT), and ultrasound. Functionalized nanoparticles can specifically target liver cancer cells, providing improved imaging resolution and accuracy for early detection and staging of liver carcinoma.

2. **Biosensors and nanodevices**: Nanotechnology-based biosensors and nanodevices offer highly sensitive and specific detection of cancer biomarkers. By utilizing nanoscale materials, such as nanowires, nanotubes, or nanowires, biosensors can detect specific molecules or biomarkers associated with liver carcinoma. These biosensors can provide rapid and point-of-care diagnosis, enabling early detection and monitoring of liver carcinoma.

3. Lab-on-a-chip platforms: Lab-on-a-chip platforms integrate multiple nanoscale components and microfluidics to create miniaturized diagnostic devices. These devices can perform multiplexed analysis of blood samples or tissue biopsies for the detection of liver carcinoma biomarkers. Lab-on-a-chip platforms offer rapid and cost-effective diagnosis with minimal sample volumes.

4. **Nanoscale imaging techniques**: Nanotechnology has enabled the development of advanced imaging techniques, such as scanning probe microscopy (SPM) and super-resolution microscopy. These techniques can visualize cellular and molecular changes associated with liver carcinoma at the nanoscale level, providing detailed insights into disease progression and facilitating accurate diagnosis.

5. **Nanoparticle-based biosensing and imaging**: Functionalized nanoparticles can be utilized for targeted detection of liver carcinoma biomarkers. These nanoparticles can specifically bind to cancer cells or specific molecules, allowing for highly sensitive detection using various imaging modalities or biosensing techniques.

6. **Liquid biopsy**: Nanotechnology-based approaches can enhance the sensitivity and accuracy of liquid biopsy, which involves the analysis of circulating tumor cells (CTCs), cell-free DNA, or exosomes in blood samples. Nanoparticles can be used to isolate and detect liver carcinoma-specific biomarkers from these samples, enabling non-invasive and real-time monitoring of disease progression and treatment response.

The integration of nanotechnology with diagnostics holds great promise for improving the early detection, accuracy, and monitoring of liver carcinoma. However, it's important to note that many nanotechnology-based diagnostic approaches are still in the research and development stage. Further validation, optimization, and clinical trials are needed to establish their clinical utility, sensitivity, specificity, and reliability.

Consulting with healthcare professionals and researchers familiar with the latest advancements in nanotechnology-based diagnostics for liver carcinoma is recommended to explore specific diagnostic techniques, ongoing studies, and their potential integration into clinical practice.

There are several drugs used in the treatment of liver carcinoma (hepatocellular carcinoma) at different stages of the disease. Here are some commonly used drugs:

- **Sorafenib (Nexavar):** Sorafenib is an oral multikinase inhibitor that targets tumor cell proliferation and angiogenesis. It is approved for the treatment of advanced liver carcinoma and is often considered the standard of care for this stage.

- **Lenvatinib (Lenvima):**Lenvatinib is another oral multikinase inhibitor that inhibits tumor growth and angiogenesis. It is approved for the treatment of advanced hepatocellular carcinoma and can be used as an alternative to sorafenib.

- **Regorafenib (Stivarga):**Regorafenib is an oral multikinase inhibitor that targets angiogenesis and tumor growth. It is approved for the treatment of advanced liver carcinoma in patients who have previously received sorafenib.

- **Cabozantinib (Cabometyx):**Cabozantinib is an oral multikinase inhibitor that inhibits tumor growth and angiogenesis. It is approved for the treatment of advanced hepatocellular carcinoma in patients who have previously received sorafenib.

- **Ramucirumab (Cyramza):** Ramucirumab is a monoclonal antibody that targets vascular endothelial growth factor receptor 2 (VEGFR2) and inhibits angiogenesis. It is approved for the treatment of advanced hepatocellular carcinoma in patients who have previously received sorafenib.

- **Pembrolizumab (Keytruda)**: Pembrolizumab is a programmed cell death protein 1 (PD-1) inhibitor that enhances the immune response against cancer cells. It is approved for the treatment of advanced hepatocellular carcinoma in patients who have previously received sorafenib and have high levels of programmed death-ligand 1 (PD-L1) expression.

- **Nivolumab (Opdivo):** Nivolumab is also a PD-1 inhibitor that enhances the immune response against cancer cells. It is approved for the treatment of advanced hepatocellular carcinoma in patients who have previously received sorafenib.

It's important to note that the selection of drugs for liver carcinoma treatment depends on various factors, including the stage of the disease, the patient's overall health, and specific biomarkers. Treatment decisions should be made in consultation with a healthcare professional who can assess the individual case and provide personalized recommendations. Additionally, ongoing research and clinical trials may introduce new drugs or combination therapies in the future..

Doxorubicin encapsulated Nanoparticles:-

Doxorubicin is a chemotherapy drug commonly used in the treatment of various types of cancer, including liver carcinoma. To enhance its delivery and improve its efficacy, researchers have explored the use of nanoparticles as carriers for doxorubicin. By encapsulating doxorubicin within nanoparticles,

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1. **Enhanced drug stability**: Doxorubicin is known to be susceptible to degradation, which can limit its effectiveness. When encapsulated within nanoparticles, doxorubicin is protected from degradation, increasing its stability and ensuring a longer shelf life.

2. **Controlled drug release:** Nanoparticles can be engineered to release doxorubicin in a controlled manner. This allows for sustained drug release over time, maintaining therapeutic levels of the drug in the target site and improving its effectiveness.

3. **Targeted drug delivery**: Nanoparticles can be functionalized with ligands or antibodies that specifically recognize and bind to receptors or markers expressed on liver cancer cells. This enables targeted delivery of doxorubicin to the tumor site, minimizing damage to healthy cells and reducing side effects.

4. **Increased drug accumulation**: Nanoparticles can exploit the enhanced permeability and retention (EPR) effect, which is characteristic of tumors. This effect allows nanoparticles to passively accumulate in tumor tissues due to their leaky blood vessels and impaired lymphatic drainage, resulting in higher concentrations of doxorubicin at the tumor site.

5. **Combination therapy**: Nanoparticles can carry multiple drugs simultaneously, allowing for combination therapy approaches. This is particularly relevant in liver carcinoma, where combination therapies may be needed to target different aspects of tumor growth and overcome drug resistance.

Doxorubicin Nanotechnology Formulations-

Doxorubicin, a widely used chemotherapy drug, has been extensively studied in nanoparticle formulations to improve its delivery and enhance therapeutic efficacy. Various types of nanoparticles have been explored for doxorubicin encapsulation, each offering unique advantages. Here are some common doxorubicin nanoparticle formulations:

1. **Liposomes:** Liposomes are spherical vesicles composed of lipid bilayers. Doxorubicin can be encapsulated within liposomes, creating doxorubicin-loaded liposomes. Liposomes improve doxorubicin's stability, prolong its circulation time, and allow for controlled release. They can also be functionalized for targeted delivery to specific cells or tissues**.**

2. **Polymeric nanoparticles:** Polymeric nanoparticles, such as poly(lactic-co-glycolic acid) (PLGA) nanoparticles, can encapsulate doxorubicin within their matrix. Polymeric nanoparticles provide controlled release of doxorubicin, protecting it from degradation and improving its stability. Surface modifications can be employed for targeted delivery and enhanced cellular uptake.

3. **Micelles:** Micelles are self-assembled nanoparticles formed from amphiphilic molecules. Doxorubicin can be encapsulated within the hydrophobic core of micelles. Micelles improve doxorubicin solubility, stability, and controlled release. Surface modifications can also facilitate targeted delivery and improve tumor accumulation**.**

4. **Dendrimers:** Dendrimers are highly branched, tree-like nanoparticles with a well-defined structure. Doxorubicin can be conjugated or encapsulated within dendrimers. Dendrimers offer controlled release, high drug-loading capacity, and surface modifications for targeted delivery.

5. **Inorganic nanoparticles:** Inorganic nanoparticles, such as gold nanoparticles or silica nanoparticles, can be used as carriers for doxorubicin. Doxorubicin can be adsorbed**,** encapsulated, or conjugated onto the surface of these nanoparticles. Inorganic nanoparticles provide unique properties, such as plasmonic heating or imaging capabilities, which can be exploited for combination therapies or imaging-guided drug delivery**.**

6. **Hybrid nanoparticles:** Hybrid nanoparticles combine different types of nanoparticles or materials to leverage their advantages. For example, a combination of liposomes and inorganic nanoparticles can enhance drug loading, stability, and targeted delivery of doxorubicin.

These doxorubicin nanoparticle formulations aim to address challenges associated with doxorubicin, such as limited solubility, rapid clearance, and systemic toxicity. They offer improved drug stability, controlled release, targeted delivery to cancer cells, and reduced side effects on healthy tissues**.**

Cisplatin Nanotechnology Formulations:-

Cisplatin, a commonly used chemotherapy drug, has been studied in various nanoparticle-based formulations to improve its delivery and therapeutic efficacy. Nanotechnology-

based formulations offer advantages such as enhanced stability, controlled release, targeted delivery, and reduced systemic toxicity. Here are a few nanotechnology formulations explored for cisplatin:

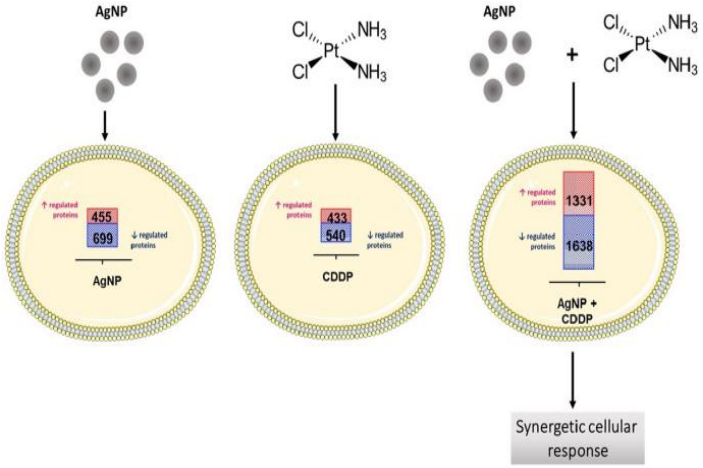

Fig. no. 8 Elucidating the cellular response of silver nanoparticles as a potential combinatorial agent for cisplatin chemotherapy.

1. Liposomes: Liposomes are spherical vesicles composed of lipid bilayers. Cisplatin can be encapsulated within liposomes, creating cisplatin-loaded liposomes. Liposomes can improve the solubility of cisplatin, protect it from degradation, and allow for controlled release. Surface modifications can also be applied to liposomes for targeted delivery to cancer cells**.**

2. Polymeric nanoparticles: Polymeric nanoparticles, often made from biocompatible polymers such as poly(lactic-co-glycolic acid) (PLGA), can encapsulate cisplatin within their matrix. Polymeric nanoparticles provide sustained release of cisplatin, improving its therapeutic efficacy. Surface modifications can be employed to enhance tumor targeting and cellular uptake.

3. Dendrimers: Dendrimers are highly branched, tree-like nanoparticles with a well-defined structure. Cisplatin can be conjugated or encapsulated within dendrimers. Dendrimers provide controlled release and can be functionalized with targeting ligands for specific tumor cell recognition.

4. Inorganic nanoparticles: Inorganic nanoparticles, such as gold nanoparticles, silica nanoparticles, or magnetic nanoparticles, can be used as carriers for cisplatin. Cisplatin can be adsorbed, encapsulated, or conjugated onto the surface of these nanoparticles.

Inorganic nanoparticles offer unique properties, such as plasmonic heating, imagingcapabilities, or magnetic targeting, which can be exploited for synergistic therapeutic effects.

5. **Hybrid nanoparticles:** Hybrid nanoparticles combine multiple types of nanoparticles or materials to take advantage of their unique properties. For example, a combination of liposomes and inorganic nanoparticles can be used to improve drug loading, stability, and targeted delivery of cisplatin.

Nanotechnology Types

Nanotechnology encompasses a wide range of techniques and materials at the nanoscale (typically less than 100 nanometers) to manipulate and control matter. Here are some commonly used nanotechnology types**:**

1. **Nanoparticles**: Nanoparticles are small particles with dimensions ranging from 1 to 100 nanometers. They can be composed of various materials, such as metals, metal oxides, polymers, or lipids. Nanoparticles have unique properties and are extensively utilized in various fields, including medicine, electronics, and energy.

2. **Nanotubes:** Nanotubes are cylindrical structures made of carbon atoms arranged in a tube-like fashion. Carbon nanotubes (CNTs) are particularly well-known and have exceptional mechanical, electrical, and thermal properties. They find applications in electronics, energy storage, and Nano medicine.

3. **Nanowires**: Nanowires are extremely thin wires with diameters on the order of nanometers. They are typically made of semiconducting materials and have applications in electronics, photonics, and sensing.

4. **Nanocomposites:** Nanocomposites are materials that combine nanoparticles or nanofillers with a bulk matrix material, such as polymers or ceramics. By incorporating nanoparticles, nanocomposites can exhibit enhanced mechanical, electrical, or thermal properties, making them useful in various industries.

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5. **Nanofilms and coatings**: Nanofilms or thin films are ultra-thin layers of material with nanoscale thickness. These films can be deposited onto surfaces to modify their properties, such as improving hardness, corrosion resistance, or optical characteristics**.**

6. **Nanolithography:** Nanolithography involves the fabrication and manipulation of structures at the nanoscale using techniques such as electron beam lithography, nanoimprint lithography**, or** scanning probe microscopy. These techniques enable precise patterning of surfaces for applications in electronics, optics, and nanodevices**.**

7. **Quantum dots**: Quantum dots are tiny semiconductor particles that exhibit unique optical and electronic properties due to quantum confinement effects. They can emit light of different colors depending on their size, making them useful in applications such as displays, imaging, and solar cells.

8. **Molecular nanotechnology:** Molecular nanotechnology involves the manipulation and control of individual molecules to create functional structures and devices. This field explores the bottom-up assembly of molecular components to build complex nanosystems with precise control.

These are just a few examples of nanotechnology types, and the field continues to evolve with ongoing research and technological advancements. Nanotechnology holds promise for a wide range of applications, including medicine, electronics, energy, materials science, and environmental sustainability.

CONCLUSION:;-

In conclusion, nanotechnology holds significant promise in the field of liver carcinoma treatment through the repurposing of existing drugs and the development of novel nanotechnology-based formulations. The use of nanotechnology in liver carcinoma repurposing offers several advantages, including improved drug delivery, enhanced therapeutic efficacy, targeted tumor accumulation, reduced systemic toxicity, and the potential for combination therapies.By encapsulating drugs like doxorubicin or cisplatin within nanoparticles such as liposomes, polymeric nanoparticles, or dendrimers, their stability and controlled release can be improved. These nanoparticle formulations can also be functionalized for targeted delivery, allowing them to selectively accumulate in

liver cancer cells while minimizing damage to healthy tissues. Nanotechnology enables the repurposing of existing drugs by enhancing their properties and effectiveness. By utilizing nanoscale carriers and modifications, drug molecules can be better protected, their circulation time can be extended, and their release can be controlled, resulting in improved therapeutic outcomes for liver carcinoma.Consulting with healthcare professionals, oncologists, and researchers familiar with the latest advancements in nanotechnology-based liver carcinoma treatment is recommended to explore specific repurposing strategies, ongoing clinical trials, and the availability of nanotechnology formulations in clinical practice.

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