Magnetic Nano Particle for Cancer Therapy and Diagnosis

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Abstract: Magnetic nanoparticles (MNPs) offering broad magnetic time and surface-area-to-volume ratios that make them captivating for hyperthermia therapy of cancer and targeted drug delivery. They can use as contrast agents for magnetic resonance imaging (MRI) and can modify the sensibility of biosensors and diagnostic tools.

Keywords: Magnetic nanoparticles (MNPs), Cancer therapy: Hyperthermia, Drug Delivery, Cancer Detection.

INTRODUCTION

Magnetic nanomaterials go to a class of highly-functionalized tools for cancer therapy owed to their inner magnetic attribute and multifunctional design that give a multimodal theranostics platform for cancer diagnosis, monitoring, and therapy.

In this review article, we have provided an overview of the various applications of magnetic nanomaterials and recent advances in the development of these nanomaterials as cancer therapeutics.

The current status of MNPs usage in cancer therapy with an emphasis on recent works. Moreover, a brief overview is presented on the importance of mathematical modeling and computer simulation for cancer therapy using MNPs.

In all likeliness, Nanotechnology and, in particular, the use of magnetic nanoparticles exist of the elements nickel, cobalt, and iron can make a momentous share.

The superior potency can be assign to the drug delivery systems: magnetic nanoparticles are functionalized by binding them to various substances, including chemotherapeutic agents, radionuclides, nucleic acids, and antibodies.

They can then be target-hunting and collected using a magnetic field. Hyperthermia can be elicited with an alternate magnetic field, supply another therapeutic option. Magnetic nanoparticles may be helpful in overcoming cancer drug resistance.

They also lend to existent a combination of diagnostic investigation and therapy in the field of "theranostics". The varied and likely results of research in the recent years offering the chance of a real advance in cancer therapy in the upcoming future.

According to the approximation by the US National Cancer Institute, nanomedicine will turn out to be trailblazing in the future day prevention, diagnostic investigation, and treatment of cancer . Nanotechnology has already recovered uses in various medical specialties.

Cancer is a condition that drive uncontrollable growth of cells within the body. The features of cancer include abnormal dividation, proliferation, loss of control, Intrusion, and metaphoric spread .

The number of new cases of cancer enhances every year, devising it one of the world's deadliest diseases. Cancers are mostly classified as leukemia, lymphoma, sarcoma, melanoma, and carcinoma.

Magnetic nanoparticles (MNPs) have gained vast attraction for cancer theranostics applications due to their unequalled physico-chemical properties, magnetic resonance imaging (MRI) contrast, facile synthesis, easy surface decorations, low toxicity, and good biodegradability that aid them to serve as prominent imagery agents, and delivery vehicles in cancer theranostics.

Magnetic Nanoparticles are largely utilized in different cancer theranostics applications considering MRI imaging, biosensors, theranostics, delivery, magnetic hyperthermy, photodynamic medical aid and photothermal ablation medical aid .

Magnetic nanoparticles (MNPs) are a most essential group of nano-materials with the potentiality to

modify current clinical therapeutic and diagnostic techniques. Utilize of nanoparticles based on magnetic in medical uses is a new and highly knowledge base field offers large potency in therapeutic and diagnostic testing, *in vitro*, and *in vivo* .

Introductory medical applications utilised iron powder or magnetite straight in treatment methods. Currently, Magnetic Nanoparticles have become a very evident tool in cancer therapy. The nanoparticles regard of nickel, cobalt, and iron can be guides by a magnetic field owing to their ferromagnetism.

In biomedicine, mainly, iron oxide nanoparticles are being in use.Nanoparticles-based magnetic iron oxide are functionalized with a chemotherapeutic agent and injectes directly into the arterial supply of the tumor .

Recently, there are nanoparticles that are state applying successfully in the diagnosis of cancer and have allowed the health care practician to image the particular areas in the body where cancer resides.

The nanoparticles are used in the physical process of destroying the tumor tissues through the MNP hyperthermia have determined that nanoparticles have multiple applications in the diagnosis and treatment of different types of cancer .(Ref.1)

Cancer is a condition that causes uncontrollable growth of cells within the body. The characteristics of cancer include abnormal differentiation, proliferation, loss of control, infiltration, and metastatic spread . The number of new cases of cancer increases every year, making it one of the world’s deadliest diseases.

Cancers are generally classified as leukemia, lymphoma, sarcoma, melanoma, and carcinoma . Lymphoma is a cancer of lymphocytes, whereas leukemia is a type of blood cancer. Sarcoma can appear in a variety of soft or connective tissues, such as bone, muscle, fat, blood vessels, or cartilage. Melanoma is another cancer type that affects and targets the skin pigment cells. The most common type of cancer is carcinoma, which can affect the pancreas, breasts, skin, lungs, or other organs .

Cancer is currently treated with surgery, chemotherapy, radiation therapy, targeted therapy, immunotherapy, stem cell or bone marrow transplant, and hormone therapy. Surgery is the most commonly used and basic method of resecting lesions. A lymphadenectomy can improve the effectiveness of surgery, but incomplete resection still increases the risk of metastasizing cancer.

To remove cancerous lesions, the use of chemotherapy involves the use of specific drugs, whereas radiotherapy involves the use of radiation. Targeted therapy delivers a drug directly to cancer cells through a variety of nanocarriers, which makes the treatment more precise and effective . Currently, other cancer therapies are not mature enough to treat cancer accurately.

In the last few years, targeted therapy, radiation therapy, and chemotherapy have all been used with nanotechnology to treat different kinds of cancer. In contemporary nanomedicine, nanomaterials are used to create early detection, diagnosis, and treatment strategies.

The potential biomedical uses are influenced by various aspects such as size, porosity, surface functional groups, electrical characteristics, zeta potential, and potential interactions.

Prioritizing the design and physiochemical properties of nanohybrid nanostructures is necessary for modern nanomedicine before addressing other important problems. The advancement of nanomedicine presents fresh opportunities to enhance current cancer treatments. Future research will focus a great deal on magnetic nanoparticles due to their unique physicochemical characteristics, scalability, and simplicity of functionalization. Iron oxide nanoparticles (IONPs), particularly magnetite and maghemite, are used in biological applications.

Once they have been broken down by the body's metabolic processes and oxygen transport, they are readily eliminated. Therefore, comprehension of the physicochemical characteristics, including features that depend on size and shape, composition, and functioning of magnetic nanoparticles, is essential for using these materials in contemporary cancer diagnosis and treatment.

The buildup of these substances at a target site in the presence of a magnetic field is essential to cancer therapy. The efficiency of magnetic nanoparticles for cancer applications such drug delivery, imaging, hyperthermia, and theranostics can be influenced by their size, shape, and surface coating. When used in cancer treatment, magnetic nanoparticles' size can affect how they behave. Because they have a larger surface area-to-volume ratio and are generally more

stable, smaller nanoparticles (<10 nm) can make.(Ref.1)

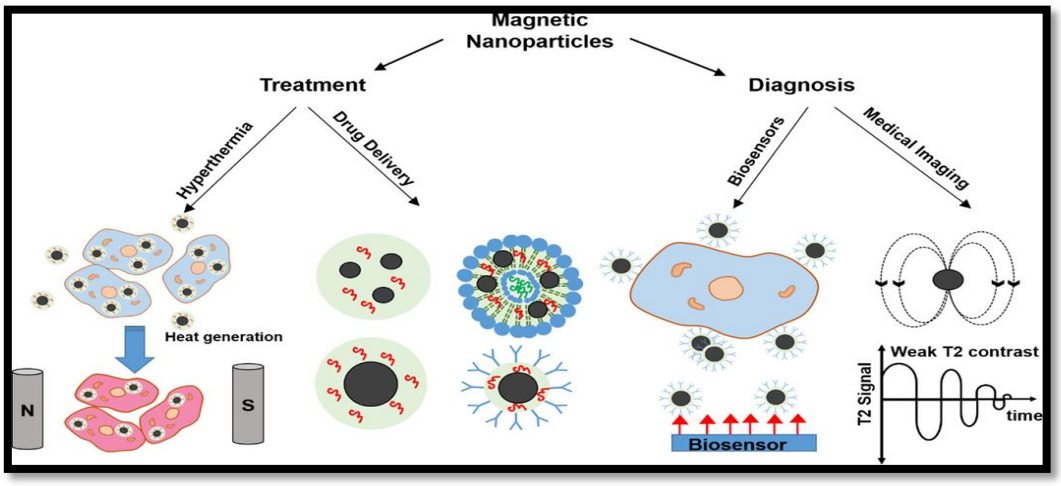

Fig.1 Various MNP forms have significant potential in drug administration, imaging, biosensing for cancer diagnosis and therapy, and hyperthermia.(Ref.1)

Synthesis, Characterization and Role of Size, Shape, and Surface Coating of MNPs in Cancer Therapy:

Although nickel, cobalt, Prussian blue, and gadolinium have all been used to create magnetic nanoparticles, magnetic iron oxide (often known as magnetite Fe3O4) NPs—which have a low systemic toxicity and strong MRI contrast properties—remain the most thoroughly studied magnetic nanoparticle-based cancer theranostics. Typically, magnetic nanoparticles are composed of a polymer covering and a magnetic core-shell.

Magnetic Nanoparticles: Toxicity, Biodistribution, Pharmacokinetics

The key factors influencing the effectiveness of magnetic nanoparticles in clinical settings are their pharmacokinetics, biodistribution, and toxicity. The pharmacokinetics and pharmacodynamics of magnetic nanoparticles inside the body are significantly influenced by factors such as hydrodynamic size, surface potential, coating, and contact with the reticuloendothelial system (RES).

The excretion of magnetic nanoparticles is significantly influenced by their size. While bigger particles may be taken up by the liver and spleen and eventually degrade or be excreted by the hepatobiliary route, smaller

In addition to improving colloidal stability and enabling covalent or electrostatic binding of therapeutic cargo, targeting moieties, and/or additional imaging probes, surface coating and functionalization of magnetic nanoparticles are crucial for adjusting the properties of these particles, including pharmacokinetics, systemic toxicity and clearance rate, nonspecific protein adsorption or cell interactions, and sustained drug release.

The conventional process for creating magnetic nanoparticles involves co-precipitation of salts with stabilizing polymer, hydrothermal.(Ref 1,2).

particles can be easily excreted through the renal route. The physical-chemical characteristics of nanomaterials, including their size, content, structure, surface charge, and The toxicity of developed magnetic nanoparticle (MNP) formulations is influenced by surface modification. First, the spleen readily sequesters nanoparticles with core sizes larger than 200 nm, while renal clearance filters out particles with core sizes smaller than 10 nm. Next, compared to nanoparticles with positive or negative surface charges, those with a neutral surface charge showed longer circulation durations.

Surface coating has been shown to play a significant effect in the movement of magnetic nanoparticles. Cole, A.J. and colleagues, for instance, demonstrated that 170 nm PEG-modified magnetic nanoparticles have a 12-hour half-life. Because of this, it's critical to carefully control the magnetic nanoparticle circulation, which has a substantial impact on the biodistribution and biocompatibility of the material.(Ref.4)

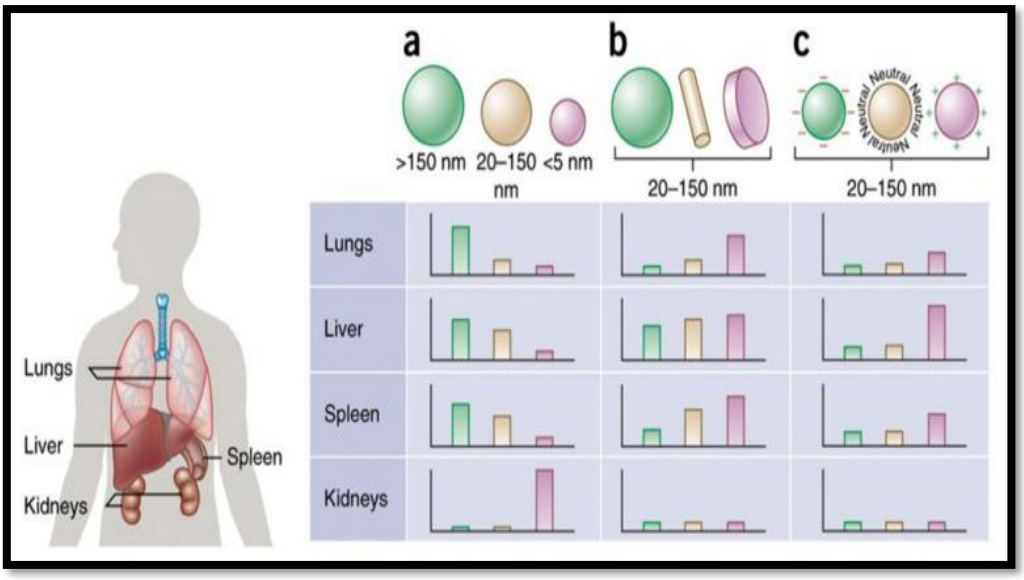

Fig 2: The lungs, liver, spleen, and kidneys are among the organs whose biodistribution is determined by the size, shape, and surface charge of nanoparticles.

a) The sizes and in vivo fates of spherical particles, such as polymeric micelles/nanoparticles, liposomes, and gold/magnetic nanoparticles, can differ. Large, inflexible particles larger than 2000 nm in diameter easily gather in the liver, spleen, and lung capillaries. It has been demonstrated that nanoparticles with a diameter of 100–200 nm can escape filtration through the liver and spleen and extravasate through vascular fenestrations in tumors (the EPR effect). The liver and spleen absorb additional nanoparticles when their size rises above 150 nm. The kidneys filter away nanoparticles smaller than 5 nm.

b) The exploration of diverse nanoparticle geometries, such as discoidal and cylindrical forms, has been made possible by the development of innovative "top-down" and "bottom up" production techniques. These shapes have been demonstrated to have unique effects on biodistribution and pharmacokinetics. Different forms of nanoparticles exhibit unique flow characteristics that alter cell membrane contacts, macrophage absorption, and circulation lifetimes considerably. These modifications ultimately affect the biodistribution of nutrients among the various organs.

c) Positively charged particles are more likely to be sequestered by macrophages in the lungs, liver, and spleen. The charge of nanoparticles originating from different surface chemistries affects opsonization, circulation times, and interaction with local macrophages of organs comprising the mononuclear phagocytic system (MPS). Nanoparticles that are neutral or slightly negatively charged circulate for longer periods of time and accumulate less in the MPS's aforementioned organs.

d) The nanoparticles in samples b and c have sizes between 20 and 150 nm. Because each panel considers the unique design factors of size, shape, and surface charge independently of the others, it represents the in vivo destinies of nanoparticles. As a result, the corresponding scales vary from panel to panel. It is important to remember that the combination of these components will determine the variation in in vivo biodistribution.(Ref.1)

A protein corona is created in a physiologically relevant environment when nanoparticles adsorb plasma proteins during circulation, a process known as opsonization.

This protein corona, which is made up of albumins, immunoglobulins, and complement system components, among other things, can modify important magnetic features like magnetization saturation and enhance receptor-mediated phagocytosis. It can also lessen the effectiveness of active targeting drugs.
These nanoparticles are sequestered and removed from the bloodstream via phagocytic uptake by

mostly resident macrophages in the liver, kidney, spleen, and lymph nodes.

Furthermore, the of Magnetic Nanoparticles in vivo is further exacerbated by the nano-bio interface and its biological interactions because of the quick adsorption of proteins onto their surface and the subsequent creation of a protein corona upon introduction to biological fluids.

Although the surfaces of magnetic nanoparticles can be altered to promote passive and active accumulation at specific locations with little to no systemic toxicity, acute iron overload in the local environment that can have harmful effects must be taken into account.

Furthermore, protein shape may alter during adsorption or result in the aggregation of magnetic nanoparticles, which could set off unanticipated, harmful biological reactions.(Ref.3,4).

Applications of Magnetic Nanoparticles

Drug Delivery Using Magnetic Nanoparticles as a Cargo Delivery: VehicleBecause of its customizable physicochemical features, including as size distribution and surface modification, nanoparticle-sized drug delivery systems have gained popularity as a drug delivery method, particularly in cancer therapies. By conjugating different biologically active therapeutics or small molecule drugs covalently or noncovalently, improving systemic circulation and biocompatibility, and using passive and active targeting mechanisms to the tumor or therapeutic site, these parameters can be designed to impart therapeutic functionality.

Chemotherapeutics and biotherapeutics: By interfering with or inhibiting cell functions, such as DNA replication, protein expression, cell division processes, or anti-apoptotic mechanisms, both biotherapeutics and chemotherapeutics seek to prevent tumor growth.

Research is now being conducted on the use of nanoparticles in radiotherapeutics to transport radionuclides, both α- and β-emitters, and/or radiosensitizers to cause DNA damage to tumor cells by generating free radicals or ionic radiation. Since radiation therapy is non-specific, using passive and active targeting to reduce off-target tissue damage gives nanoparticles a distinct edge over existing methods. Moreover, combination medicines, like gene therapy or chemotherapy, make use of nanoparticles for a synergistic effect.

I. Microneedles as Natural Anticancer Agents:

a. Cancer Immunotherapy: This category includes a variety of treatments that target solid tumors directly, stop the growth of cancer cells, and identify cancer cells using the patient's immune system.Benefits of combining nanoparticles with cancer immunotherapy techniques include a targeted delivery vehicle that can be precisely adjusted to have the necessary surface changes, charge, size, and shape to maximize delivery efficiency.

Furthermore, by combining hyperthermia therapies for maximum therapeutic efficacy, magnetic nanoparticles can be further engineered to impart additional therapeutic advantages. For tracking administration in vivo, these nanoparticle immunotherapeutic formulations are frequently functionalized as both an MRI contrast agent and a fluorescent probe.

I. MNPs as Anti-Cancer Agent: A number of organizations have also employed magnetic nanoparticles as an anti-cancer agent. By adjusting the iron levels by the use of ferumoxytol, an FDA-approved medication for anemia, Zanganeh et al. demonstrated the killing of cancer cells in lung, liver, and early breast malignancies. Ferumoxytol-treated macrophages produced elevated mRNA levels linked to pro-inflammatory Th1-type responses. In a mouse model with aggressive adenocarcinomas, ferumoxytol at a dose of 10 mg Fe·kg−1 showed significant tumor shrinkage as shown by H&E staining, bioluminescence imaging, and Prussian blue staining. According to the authors, ferumoxytol triggers immune cells to adopt an anti-tumor "M1" phenotype reaction, as evidenced by a rise in pro-inflammatory M1 macrophage density.

III. MNPs as a Tumor Ablation Therapy Catalyst:

Magnetic Hyperthermia: The use of magnetic nanoparticles in tumor ablation therapies is gaining significant attention. One such treatment is magnetic hyperthermia, which is the death of necrotic tumors by the heat produced by the magnetic nanoparticles

in the presence of an alternating external magnetic field.

Photothermalich uses light-induced heat produced by magnetic nanoparticles to kill cancer cells. Photodynamic treatment, which uses cytotoxic singlet oxygen species produced by magnetic nanoparticles coupled with photosensitizing agents to kill cancer cells.

IV. hen used in medication delivery, nanoparticles can solve problems related to the administration of traditional anti-cancer medicines while also improving drug stability. For chemotherapy, superparamagnetic iron oxide nanoparticles (SPIONs) coupled with doxorubicin and functionalized with PEG were created (SPIO-PEG-D).

The half-life of doxorubicin was increased by conjugating it with PEG onto the surface of SPIONs. An in-vitro experiment showed that for HT-29 cancer cells, SPIO-PEG-D causes decreased DNA expression and enhanced cell death. Furthermore, in-vivo tests shown that the use of this drug delivery method in conjunction with an external magnetic field reduced the incidence of cardiotoxic and hepatotoxic adverse effects.

V.The depth to which the magnetic field may pierce is the application of magnetic nanoparticle. Since the magnetic field weakens with distance, it is challenging to penetrate the body beyond 2 cm from the skin.

However, the magnetic field can easily permeate the body up to 2 cm from the skin. Nevertheless, to avoid the limitations of external magnetic fields, internal magnets can be positioned close to the tumor by minimally invasive surgery.

VII.The progressive rise in temperature to 40–43 °C is known as hyperthermia. It causes cancer cells to be destroyed and enhances the effects of radiation and chemotherapy. This method's incapacity to locally heat cancer cells is a problem.

Nevertheless, this problem can be avoided by injecting MNPs that are directed towards particular locations and using an external magnetic field to produce localized heat. Since this tailored method doesn't harm nearby healthy tissues, it could increase the safety and effectiveness of hyperthermia.

VIII.Cancer therapy can be applied non-invasively by magnetic hyperthermia. This method provides an alternative for some malignancies that might be challenging to remove surgically and for those that are located close to important organs.

Treatment options may extend beyond specific tumors since magnetic hyperthermia addresses the problem of nonselective ionizing radiation linked with conventional radiotherapy. The most common nanoparticle materials for magnetic hyperthermia are magnetite and maghemite.(Ref.1,2).

Cancer Diagnosis:

Early cancer detection significantly increases the chance of recovery. Thus, the key to lowering the patient death rate is early identification and prompt diagnosis of cancer.

Optical fluorescence imaging, ultrasound (US) imaging, photoacoustic (PA) imaging, computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI), and single-photon emission computed tomography (SPECT) are among the techniques used.
Because of its superior signal-to-noise ratios, outstanding spatial resolution, precision, capacity to create 3D pictures, good contrast with soft tissue, and lack of radiation, magnetic resonance imaging (MRI) is the best option.

A CT scan uses X-rays to provide finely detailed images of blood arteries, soft tissue, bones, and internal organs. Ionizing radiation, or X-rays, are a significant drawback of the CT technique.

Imaging using a PET scan is done using nuclear technology. This method sheds light on how chemicals enter and exit particular tissues to help with disease diagnosis.

The foundation of this technique is the identification of pairs of gamma rays released by a radionuclide in a physiologically active chemical that emits positrons. Using ionizing radiation (beta and gamma rays) is thought to be this method's primary drawback.

A tomographic imaging technique used in nuclear medicine that also uses gamma rays is called SPECT. This technology is identical to traditional CT imaging, with the exception that it uses a gamma camera to detect nuclear radiation. This is the reason that a radioisotope substance that emits gamma rays, such gallium (III) isotope, is injected into the circulation.(Ref.3,4).

Cancer Therapy and Drug Delivery

I. Hyperthermia: The application of targeted therapeutic heating of cancer cells is being studied in relation to the induction of MNPs by exposure to an adequate Alternating magnetic field (AMF).

A therapeutic procedure known as hyperthermia involves raising the body's temperature above normal physiological range in a particular tissue or throughout. Within a tumor, MNP heat leads to the death of tumor cells.Because the pH at the malignant microenvironment is lowered, which leads to poorer thermotolerance, cancerous cells are more susceptible to hyperthermia than normal cells.

The tumor overheats as a result of an unorganized vascular network and decreased blood flow within the malignant tissue, which slows the tumor's rate of convective cooling. Conversely, conduction and convection allow healthy tissue with well-organized blood flow to transfer excess heat to nearby tissue.

Because of this, cells in malignant tissue become much less viable between 41 and 46 degrees Celsius, while cells in healthy tissues are able to dissipate heat and remain viable.

In a typical hyperthermia treatment, heat can be produced using radiofrequency, microwaves, infrared radiation, ultrasonic waves, and hot water. Research is also being done on the induction of MNP-based hyperthermia as a supplement to traditional cancer treatment techniques like radiation and chemotherapy. Depending on the size of the area being treated, hyperthermia therapy can raise the temperature locally or overall.(Ref 1,3,5).

II. Mechanism of MNP-based heat generation

Weiss domains, which are multi-magnetic domains, make up ferromagnetic materials. Due to hysteresis loss that occurs throughout a magnetization cycle, they are able to generate heat. All of the magnetic domains in ferromagnetic materials are compelled to align with the direction of the applied magnetic field (AMF) in order to achieve a lower energy state.

The magnetization does not return to its initial state (that is, the state before the applied magnetic field) when the AMF is removed. Applying an opposite magnetic field, or coercive field, reduces the residual magnetization.

The ferromagnetic material's magnetization curve with a hysteresis loop. The hysteresis loss is represented by the region inside the hysteresis loop.

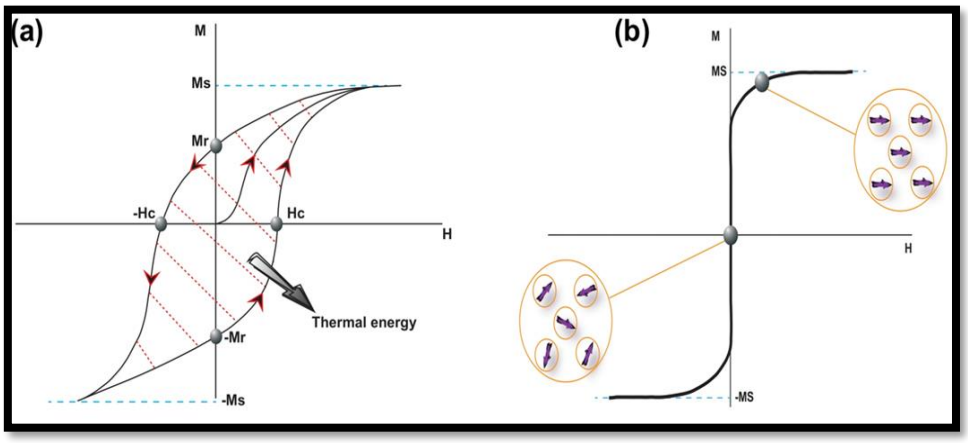

Fig 3 Schematic drawing of (a) a hysteresis loop of a ferromagnetic material and (b) typical plot of a superparamagnetic material.(Ref.1)

Drug Delivery of MNPs to the Tumor Site

MNPs can be injected locally using hypodermic needles or catheters. By subjecting MNPs to an external magnetic field close to the target tissue, they can also be reliably and locally controlled within the malignant spot.

The direct injection approach involves injecting magnetic fluid containing a certain concentration of MNPs straight into the malignant tissue. Since it

doesn't require any further assistance for particle localization, this approach is the simplest.

The MNPs are administered intravenously in a methodical manner. The enhanced permeability and retention (EPR) properties of MNPs generate a rise in their concentration in the circulation.

The vascular architecture of tumors differs from that of healthy organs. Tumor tissue's damaged vasculature can help tumor cells develop by providing them with nutrients and oxygen, but it can also make it easier for macromolecules and nanoparticles to enter the tumorsite.(Ref.

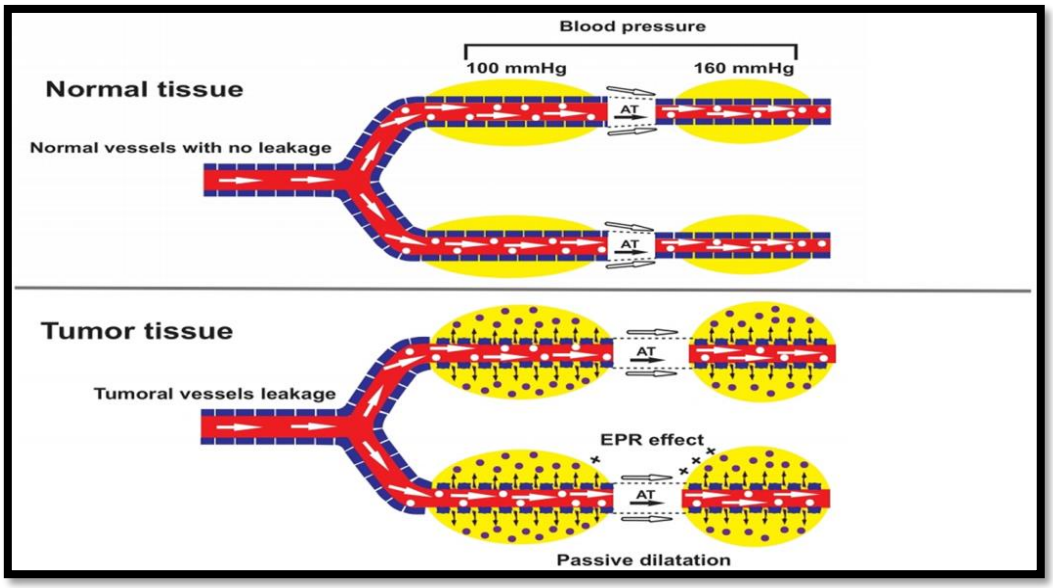

Fig 4 Schematic representation of the EPR effect in normal and cancer tissue.(Ref.1)

II. MNPs for hyperthermia-based therapy

Materials for magnetic nanoparticles (MNPs) utilized in hyperthermia therapies include Mn, Fe, Co, Ni, Zn, Gd, Mg, and their oxides.

Even though pure metals have a high saturation magnetization, their uses in biomedical engineering have been restricted because of their possible toxicity and instability in the human body.

Because they are more biocompatible and stable in vivo than metals, metal oxides are a more desirable option for use in medicine.

The well-known magnetic substance magnetite (Fe3O4) can be stabilized by a variety of ligands, including hydrogel, lauric acid, polyvinyl alcohol, cationic liposomes, and dextran.

Ferrites, namely cobalt ferrites (CoFe2O4), manganese ferrite (MnFe2O4), nickel ferrite (NiFe2O4), and lithium ferrite (Li0.5Fe2.5O4), are the foundation of another class of MNPs.

Ferromagnetic nanoparticles, such as those doped with Au in Fe and Zn/Mn in iron oxides (ZnxMn(1−x)Fe3O4), can be widely used in applications related to hyperthermia. FeCo metallic nanoparticles heat up quickly (1300–1600 W/g).(Ref.2,4).

Active ligand	Surface receptors	Cancer cells	Applications
RGD peptide	Integrin $\alpha_v\beta_3$	Breast carcinomas	siRNA delivery (47)
		Glioblastoma	Brain tumor diagnosis by MRI and near-infrared fluorescent (NIRF) imaging (79)
		Activated platelets	Thrombus visualization by MRI (80)
CTX (chlorotoxin)	MMP-2 (matrix metalloproteinase-2)	Gliomas medulloblastomas	Brain tumor diagnosis by MRI (81, 82)
Herceptin	HER2 (human epidermal growth factor receptor 2)	Breast cancer	Platin delivery (83, 84)
			Breast cancer diagnosis by MRI (7)
			Localized hyperthermia (85)
Anti-TfR (transferrin receptor) MAb	TfR (transferrin receptor)	Hematopoietic and neural progenitor cells	MR tracking of cell differentiation and migration (86, 87)
		Gliosarcomas	MR detection of gene expression (88)
Tf (transferrin)		Cervical cancer	Gene delivery (89)
LHRH (luteinizing hormone-releasing hormone)	LHRHR (luteinizing hormone-releasing hormone receptor)	Breast cancer	Targeted Fe-induced apoptosis in cancer treatment (90)
		Ovarian cancer	Breast tumor and metastases detection by MRI (91, 92)
FA (folic acid)	FAR (folic acid receptor)	Breast cancer	Early diagnosis by MRI (93, 94)
		Epithelial carcinomas	

Fig 5 Magnetic Nanoparticles used in Cancer Therapy(Ref.1,2).

CONCLUSION

MNP systems for various applications in pre-clinical cancer theranostics. Few MNP formulations have demonstrated success in clinical studies, despite their potential. MNPs are innovative therapeutic agents that have the potential to completely change how cancer is diagnosed and treated.

MNPs can be produced using a variety of synthetic methods. The most common methods are co-precipitation, thermal breakdown, hydrothermal, and polyol synthesis. MNPs' biocompatibility has been markedly improved by functionalization.

Thus far, organic and inorganic polymers have been the most widely used functionalizing agents. Functionalization plays a major role in the use of MNPs as potential instruments in biomedical applications such medication administration, magnetic hyperthermia, and diagnostics.

In order to overcome complex challenges like comprehending human nano-bio interactions, getting past physiological and technological barriers unique to a particular cancer type, escaping the late endosome/lysosome system into the cytosol within tumor cells, and long-term toxicity, critical information still needs to be researched further.

Biological obstacles impede the localization of treatments at the target location for nanoparticles, especially magnetic NPs. As a result, the use of NPs as effective drug delivery vehicles for theranostics is limited.

Nano particles opsonization and clearance by the MPS, nonspecific distribution, endosomal escape, cellular internalization, and drug efflux pumps are some of these challenges. Appropriate surface coating techniques are needed to prevent MNPs from aggregating and producing ROS, which would otherwise be hazardous.

Along with recent advancements in improving synergistic multimodal therapies, regulated and sustained drug release, and active targeting, MRI monitoring of nanoparticles has proven to be a potential element of MNP-based platforms.One significant feature of using magnetic nanoparticles is "theranostics," which combines the goals of therapy and diagnosis.

Magnetic nanoparticles have already shown great promise in the treatment of cancer. There are a lot of applications for them. Drug delivery enables the targeted distribution of a broad range of chemicals, including radionuclides, antibodies, nucleic acids, and chemotherapy drugs, to the intended site of action.
Adjuvant therapy that combines drug administration with heat can enhance the intended anticancer effects. However, localized hyperthermia can also be employed in isolation with the help of magnetic nanoparticles.

To yet, nevertheless, no one MNP formulation has been authorized for use as a cancer treatment. In addition, the regulatory agencies have recently started a number of regulatory safeguards to ensure the safe and effective basic and translational development of MNPs in the wake of the withdrawal of a few products based on MNPs.

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