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# Recent Advances of Magnetic Nano-Particles in Biomedical Applications

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**Abstract**: Magnetic nanoparticles have become increasingly important for magnetically assisted medication delivery, MRI, tissue repair, gene therapy, and hyperthermia. The morphological structures of magnetic materials have received a great deal of attention due to their unique surface chemistry, non-toxicity, biocompatibility, and application to various scientific applications, especially due to their inductive magnetic moments. This article assessed major experimental approaches from current research, also their potential benefits and drawbacks in terms of medical implementation in the future. This study is growing in importance as it assists to the invention of novel cancer treatments.

**Index Terms**: Drug delivery, Magnetic particles, Tissue repair, MRI, Gene therapy, Hyperthermia

## 1 INTRODUCTION

Recently, there has been a growing focus in the medical sector on the applications of magnetic nanoparticles. Particles with a diameter of fewer than 100 nanometers are known as nanoparticles . They have distinct characteristics like a high surface volume ratio and high reactivity. The review article describes the importance of MNPs in biomedical applications, with their advantages and disadvantages. Magnetic nanoparticles are a special type of nanoparticle that consists of a magnetic field. As a result, MNPs have been utilized in a wide range of medical settings, such as magnetic resonance imaging (MRI), hyperthermia, tissue repair, targeted drug delivery, cancer treatment, incorporating cell labeling and targeting in cellular treatment, as an aid to separate and purify cell populations for cell-biology research, and so on [2]. MNPs have large magnetic moments and are used in biomedical applications due to specific features such as biocompatibility, stability, and flexible surface modification. MNPs are manufactured from a range of metal elements and their magnetic oxides, either alone or in composites. Different alone or in composites metal elements and metal oxides that have magnetic properties are used to make MNPs. For more successful treatments, use metals with a lot of saturation like metals in transition such as Ni, Co, and Fe, or oxide of metals like $Fe_2O_3$, $Fe_3O_4$. Because of its great biocompatibility and low toxicity, superparamagnetic magnetite, such as $Fe_3O_4$, is the most frequently employed iron oxide among MNPs. [2]. MNPs of this size have only one magnetic domain, in which all of the magnetic moments of solitary

atoms in MNP have been connected in a consistent manner to create a massive total magnetic moment. Thermal oscillations irrevocably change the magnetic moments of MNPs in different orientations at a particular temperature, leaving the MNP sample without residual magnetization [3]. For biological and biomedical applications, smaller iron oxide MNPs are the ideal option. Because of their physicochemical properties, including as stability, biocompatibility, and ease of production, MNPs have been found in numerous of biomedical applications. External magnetic fields can interact with MNPs. At dipoles, various sorts of force and torque are developed and produced by an external magnetic field, resulting in energy translation, dissipation, and rotation. MNPs are made up of a number of materials with different physical and magnetic properties depending on how they're employed. However, the most crucial issue to examine in biomedical research is their potential biocompatibility/toxicity [2].

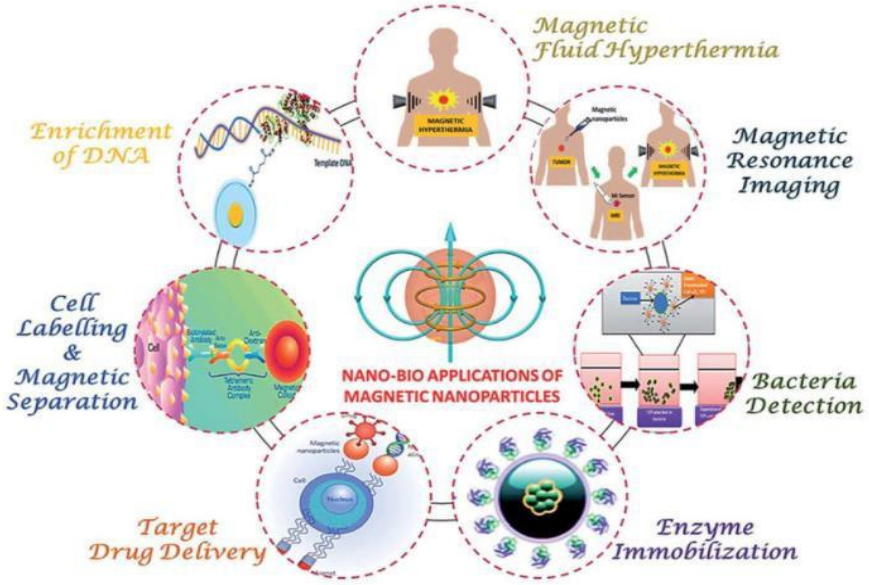


Fig.1 Bio medical applications of MNPs [4]

There are several studies done on the magnetic nano particles. Karunaratne and his colleagues patented a method for manufacturing a mixture of high-purity MNPs made from natural ore. Stable dispersions of long-chain carboxylic acid-stabilized MNPs dispersed in alcohol are the subject of the formulations and procedures. These compounds have uses in advanced biomedical research [5]. Using a unique top-down technique, Priyadarshana et al. produced MNPs from a natural iron oxide ore with high-purity. Surface modified MNPs developed from top-down de-structuring of this ore in the presence of oleic acid. The resulting nanoparticles are spherical in shape and range in size from 20 to 50 nanometers in particle sizes [6].

## 2. BIOMEDICAL APPLICATIONS OF MAGNETIC NANOPARTICLES

### 2.1. DRUG DISTRIBUTION

MNPs is utilized to distribution of drugs with precision of drugs with precision in the battle against cancer. Nanoparticles are loaded with medications and towards the direction and focused in tumor locations via an outside field of magnetic, which is has been successfully prepared through the use of appropriate groups like PEG 50 or poly-methyl methacrylate (PMMA 49). In these applications, nanoparticle charge, surface chemistry, and size are necessary to make sure that they can remain in circulation for a long period of time [7]. Magnetic drug delivery concentrates MNPs on illness sites by injecting them into the bloodstream. MNPs have been utilized to administer drugs in a variety of ways. The spinel $Co_{0.5}Ni_{0.5}Fe_2O$ system, for example, has been shown to be capable of drug delivery through a variety of approaches. The nano nickel ferrite could possibly be used to deliver drugs [8].

As a result, nanoparticles with ten to hundred nanometer size ranges are ideal for delivery of drugs [9]. Extravasations and clearance efficiently remove particles smaller than 10 nm, hence the lower threshold is justified. The upper limit is unknown; according to current research, nanoparticles with a diameter of fifty to hundred nano meter, which is smaller compared to the spleen cutoff of two hundred nano meter, can infiltrate big tumors following systemic injection [3] .

MNPs are primarily used to distribute antibodies, chemotherapeutic drugs, and some other illness-related pharmaceuticals to sick locations in the patient's body. Since 1970, some Scientists are looking into the usage of MNPs and target medicine delivery using micro nanoparticles. Lubbe and colleagues conducted the first clinical experiment for target medication delivery in 1996. Various methods of production of magnetic dig carriers for drug administration have been used in some studies [10].

The nanocarrier can effectively reach "Hela" cells, which could help in the creation of capable of controlled-release functioning nanocarriers. Furthermore, the stimuli-responsive particles assemble and are regulated by themselves. Other nanoparticles lack the biocompatibility and surface architecture of SPIONs (superparamagnetic iron oxide nanoparticles). Linking SPIONs to specific ligands or proteins has sparked a lot of interest in medication delivery applications [11]. The stimuli-responsive particles can change their aggregation or morphologies behaviors under diverse physical conditions to affect the drug release behaviors [12].

## 3. CANCER TREATMENT

The essential components of a cancer theranostic system are the production and design of customised NPs including multifunctional properties that are overcoming the limits of traditional cancer diagnoses and

treatment options. For cancer diagnosis and visualization, nanoparticles is being used to make imaging probes at the nanoscale. Furthermore, nanoparticles are also being as carriers to transfer genes, anticancer medications, and proteins to tumor sites more effectively due to their increased infiltration and retention impact. Theranostic nanomaterials' many properties are a direct outcome of their physical-chemical, optoelectronic, and magnetic capabilities, as well as the precise design of the intelligent nanodevice [1]. Theranostic nanomaterials' many properties are a direct outcome of their physical-chemical, optoelectronic, and magnetic capabilities, as well as the precise design of the intelligent nanodevice [13].

Gold nanoparticles (GNPs), superparamagnetic iron oxide nanoparticles (SPIONs), carbon nanodots (CDs), and graphene oxide (GO) are among the MNPs that have shown promising biomedical properties, particularly in cancer theranostics [14]. GNPs are a form of colloidal gold with a diverse shape and set of properties. SPIONs have been studied as effective contrast agents in combination with chemo- and magnetotherapy in cancer magnetic resonance imaging (MRI) [15]. Gold, being a noble metal, has physical-chemical plasmonic properties that are critical for cancer theranostics since they are responsible for both imaging and therapeutic properties [13].

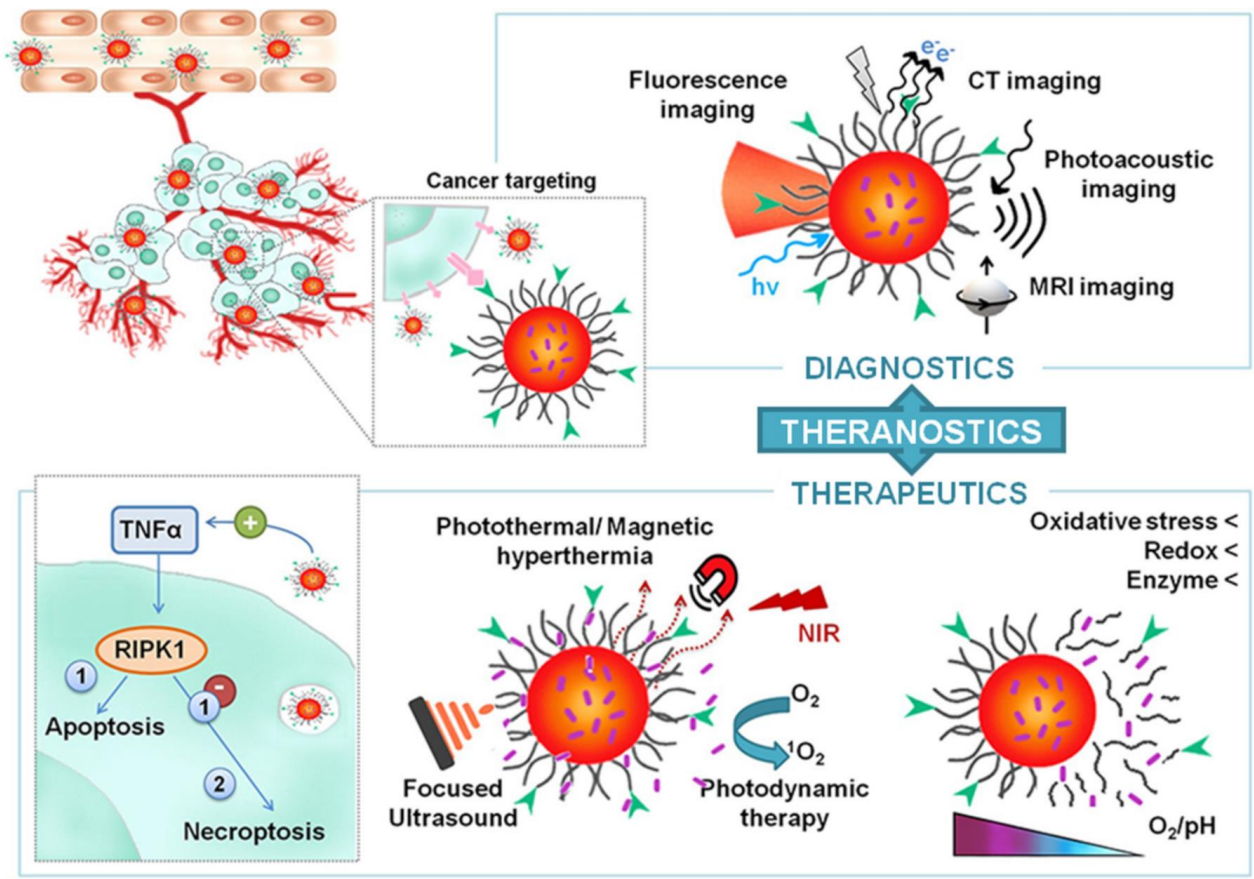


Fig. 2 Conceptual representation of the Cancer theranostics [16]

Due to their higher metabolic rates, thermal sensitivity is higher in cancerous cells than it was in normal cells, making hyperthermia the ideal cancer treatment. In magnetic hyperthermia, a novel treatment for treating cancer, a source of external alternating magnetic field (AMF) is employed to generate hot in suspensions of MNPs inside the human's body. Cancer and healthy cells are heated to 41 °C to 47 °C then show signs of apoptosis and also that cells are heated above 50 °C then show signs of necrosis. Due to the lower pH in the malignant microenvironment, Hyperthermia makes malignant tumor cells more sensitive than normal cells, resulting in worse thermotolerance. While inflicting little damage to healthy cells, both apoptosis and necrosis can destroy cancer cells .This technology is viewed as a possible approach for cancer treatment because of its focused hysteric heat was targeted, and background tissue heating was decreased. One of the most important benefits of MNP-based hyperthermia is that cancer cells are targeted for death while healthy tissues are spared [2].

Magnetic nanoparticle-based heating causes hyperthermia. This is the best generate system of Hyperthermia because,

a) It enables non-invasive cell temperature raising to therapeutic levels.
b) Magnetic Resonance Imaging (MRI) can be used to see it, which combines diagnostic and therapeutic techniques into a single particle.
c) Functionalization of the particles allows them to be used in conjunction with other therapies such as chemotherapy or radiotherapy.

Injecting nanoparticles into tumors while heating them utilizing alternating magnetic fields to obtain acceptable temperatures is known as magnetic nanoparticle hyperthermia. Neel relaxation and brown relaxation are the heating mechanisms of magnetic nanoparticles. MNPs aren't the only ones who benefit from this heating procedure and can be used on other materials that can absorb near-infrared (NIR) light, like carbon nanotubes or gold nanoparticles. This is a prevalent misconception [7].

Because of their outcomes in many disciplines, MNPs (Magnetic Nano-Particles) have gotten a lot of attention in the last decade. The most prominent advantages of MNPs-based hyperthermia therapy are magnetism-assigned targeted killing of cancer cells and deep tissue penetration without harming healthy tissues. [8].

Samali Liyanaarachchi et al. created plumbagin-functionalized magnetite nanoparticles (PFMNPs) by extracting plumbagin from the roots of Plumbago indica L. The photo-thermal stability of plumbagin was improved after it was functionalized with magnetite, demonstrating great control over release behavior. The antibacterial efficacy and biocompatibility of the produced PFMNPs, as well as the slow-release characteristic of plumbagin, showed promising results, indicating that these materials could be used in the pharmaceutical industry. The magnetic capabilities of the magnetite plumbagin nanohybrid are a beneficial

addition to the product, which might be used in antibacterial medications as well as antifungal, anti-inflammatory, and anticancer compositions [17].

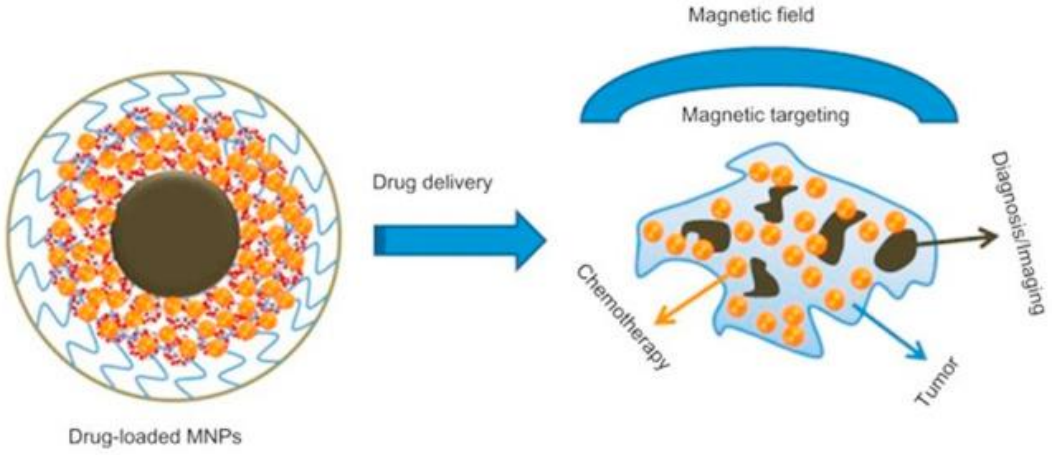


Fig. 3 Schematic representation of MNPs based Hyperthermia system [18]

## 4. TISSUE ENGINEERING

Growth agents, three-dimensional biodegradable scaffolds, and seed cells are used in tissue engineering to strive to achieve tissue growth without causing harm. This method involves the autologous cell culture in vitro, the combination of cells with bio-based three-dimensional (3D) scaffolds, and the encouragement of the re-establishment of its original structure [8]. Intensive use of nanotechnology has garnered a lot of interest in case repair during the last decade. Researchers employ nanotechnology, especially for bone repairs and orthopedic and dental implants. There have been several micro/nanofabricated implantable goods on the market like nano-artificial bone and micro/nano biochips. Some experimental items like bone restoration materials and coating materials are tested not only on the market but also in the laboratory [7]. Different methodologies have resulted in different tissue engineering platforms. The most common jetting technologies include pressure-assisted/driven jetting, aerodynamically assisted jetting and threading, electrospray, electrospinning, laser-guided writing, spinning, and inkjet printing. Methodologies based on MNP and methods of scaffold building used mostly to control cell function. Bioactive and growth factors, as well as mechanical transduction channels that can alter and govern cell behavior by translating mechanical stress into biochemical markers within the cell, are primary regulators of the cell activity [19].

As a new idea Magnetic nano-particles can be used for cell therapy. The first issue was magnetic labeling for MRI monitoring or observation of cell movement. External magnetic fields load cells with magnetic nano-particles directed and focused on the desired sites for tissue repair. Mesenchymal stem cells (MSC), natural killer cells, and erythrocytes are several cell types that have been used to test this strategy. To treat bone cancer, a magnetic field guides natural killer cells toward human osteosarcoma cells [3]. In 2000,

MNPs were used on stem and progenitor cells, but in 1930 they were used for intracellular labeling [20]. Tissue healing and regeneration need the establishment of a tissue engineering complex. The present situation is that cells tend to loiter on the surface of the material, preventing them from entering the scaffold. Recent research has discovered that using magneto-mechanical drive, a three-dimensional scaffold can have cells pushed to the center [21]. Iron oxide particles, which are simply made via precipitating iron salt, are the most often used MNPs [19]. The magneto ferritin nanoparticles were found to be a biologically viable alternative to magnetic cellular spheroids, permitting them to be used as tissue-engineered construction materials. Cell viability was unaffected by the magnetic ferritin nanoparticles and had a much higher cell concentration than other MNPs used in tissue applications. The Janus structure of magnetic nanoparticles (JMCS) is associated with the MNPs' spatial control, which permits them to divide into two domains: extracellular and cells MNPs. [8].

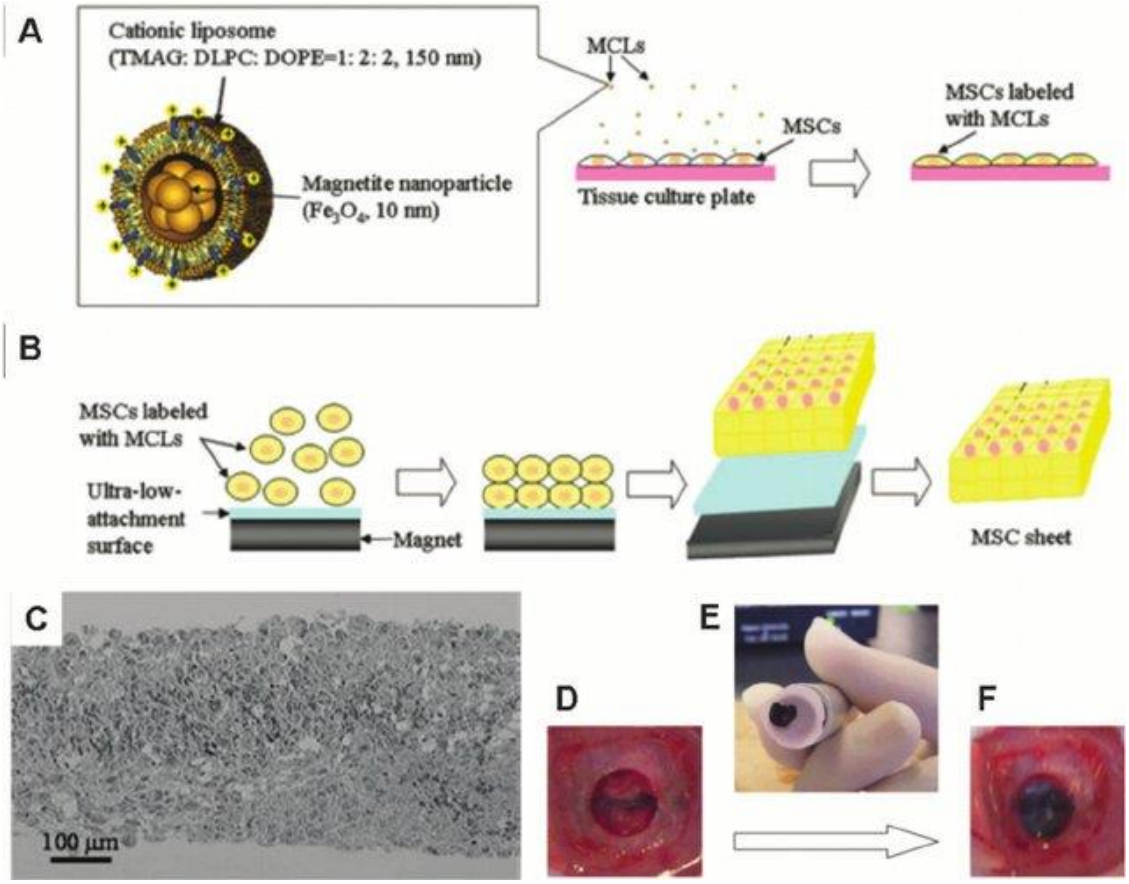


Fig. 4 MNPs based Tissue engineering method [22]

## 5. MRI (MAGNETIC RESONANCE IMAGING)

MRI has been one of the most extensively utilized and effective non-invasive clinical diagnosis

technologies available today because of the penetration depth, strong contrast in soft tissue, and spatial resolution [23]. Because of its noninvasiveness and lack of radiation, magnetic resonance imaging (MRI) is the most commonly utilized method in medicine. Image flexibility and great spatial resolution are advantages of MRI, as are good contrast in soft tissues and the capacity to provide information about blood circulation and blood vessels. Furthermore, images are collected without the use of ionizing radiation or radiotracers, which could have unintended negative consequences. But its disadvantage is low sensitivity. Using magnetic ions and magnetic particles have developed the contrast of MRI and enhanced the information of images. Furthermore, contrast chemicals are utilized to improve MRI imaging of tissues and organs by altering the water protons' relaxation durations [7]. MRI is a technique used in both diagnostic and therapeutic radiology. The fast advancement of imaging technology like positron emission tomography (PET), MRI, optical, and ultrasound imaging has aided in the early the detection of illnesses, comprehending biological beings' essential molecular aspects, and evaluating medical treatment. The MRI's advantages include tremendous versatility in imaging, high levels of patient acceptance, and the ability to look at anatomical and physiological data [8]. The Food and Drug Administration (FDA) has authorized SPIONs in a variety of compositions as MRI contrast agents such as Combidex® for imaging of lymph node metastases, Feridex IV® for imaging of spleen and liver, and Lumiren® for bowel imaging [23]. In MRI applications, MNPs are extensively used. Iron oxide NPs could be utilized to image tumor and monitor in vivo iron oxide doped stem cells. The usage of MNPs as CAs is gaining popularity since they are able to easily integrate various contrast effects and perfect their structure. Advanced MRI CAs with MNPs and proper targeted agents may be able to identify different forms of cancer in MRI with extreme sensitivity. Parallel imaging has recently been developed to boost speed and decrease imaging time, resulting in poorer patient throughput and increased movement artifacts [8]. MNPs and appropriate targeted therapeutics in advanced MRI CAs can enable ultrasensitive cancer diagnosis using MRI. Recent research has focused on developing parallel imaging to improve speed and reduce imaging time, resulting in lower patient throughput and increased movement artifacts [3]. Iron oxide nanoparticles (IONPs) for MRI have emerged as a potential alternative to standard contrast agents (CAs) due to their good magnetic characteristics and strong biocompatibility [24]. The MRI is detecting the disease might be considerably improved, and diseases could be recognized at an earlier stage. After MNP injection into mice, cells visualized by MRI and magnetic separation techniques were used to extract cells from excised tissues, and they were still able to distinguish between them. SPIOs connected with radioactive tracers are used to create novel particles and that are used to integrate these various imaging techniques like MRI and PET (Positron emission tomography). To obtain a tomographic image, the novel magnetic particle imaging (MPI) method uses the nonlinear magnetization reaction of superparamagnetic nanoparticles [25]. Iryna

Antal et.al investigated the physicochemical characteristics of MNPs in magnetic fluids that were positively charged, where various amino acids are used to make the MNPs functional such as lysine, tryptophan, and glycine. They also studied the MRI relaxivity and the impacts of amino acid–MNP complexes as superparamagnetic nanoparticles. The experimental evidence based on the magnetic field, acidic acid coating on the relaxivity qualities of amino acid-MNP complexes has a unique application as a molecular contrast imaging agent [26]. Stephen et.al utilized the iron oxide nanoparticles (SPIONs) as new MRI agents of contrast for multifunctionality and enhanced in vivo kinetics due to its superparamagnetic properties like desirable, degradability, and easily modifiable surface characteristics. Due to the large surface area of SPIONs, that enable the insertion of biologically active molecules cost-effectively like non-invasive brain tumor imaging with penetrating peptides. Multifunctional SPIONs can be structured to include complementary imaging modalities that would give extra truthful data in vivo when used together [23]. The review of Ashish Avasthi et.al demonstrated the crucial factors in the development of IONPs for MRI applications, which focused on the production of the inorganic core, surface modification techniques to produce biodegradable IONPs, with a special emphasis on tumor models. The superparamagnetism leads to great biocompatibility and high relaxivity, that could be integrated into iron metabolism, as well as the ease with which target molecules can be functionalized on their surfaces for molecular imaging [24].

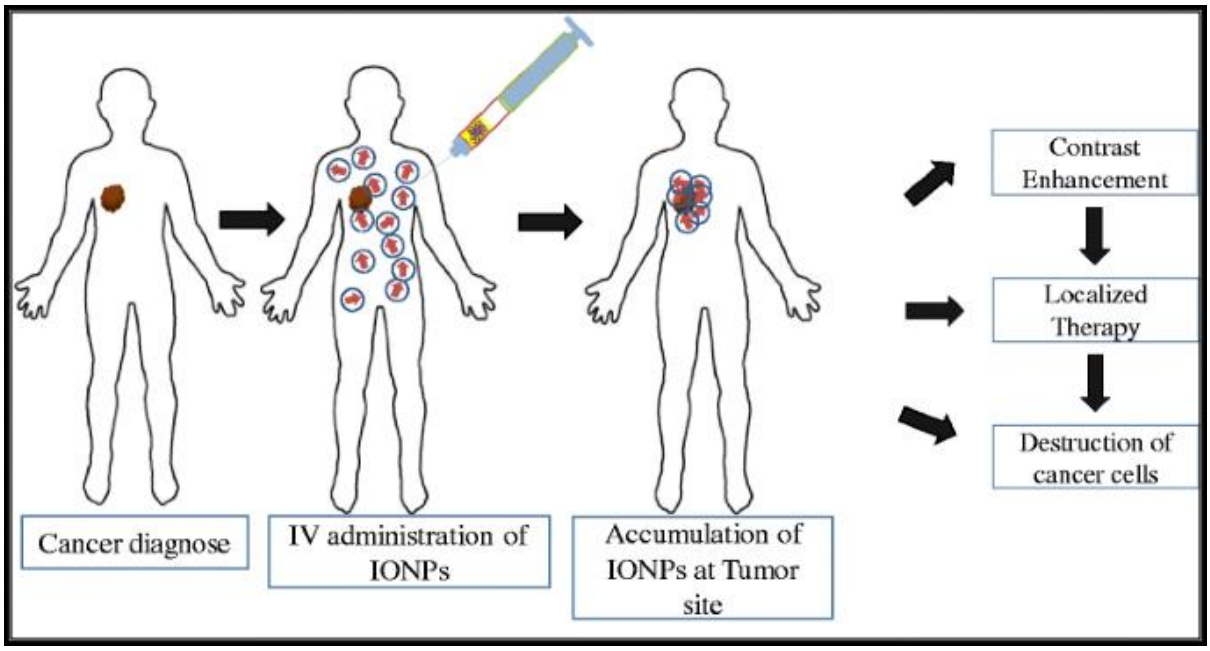


Fig. 5 MRI based MNPS contrast agent [27]

## 6. GENE THERAPY

The technique of transferring foreign Genes to the cell of the human host known as gene delivery is a

crucial component in livestock and agricultural genetic modification [28]. which is a disease treatment option for viral infections, genetic abnormalities, and cancer. As a result, many MNPs are being developed for cancer diagnostics and other treatments. Viral and non-viral delivery vehicles were utilized for the prostate cancer's gene therapy treatment [24]. Superparamagnetic NPs provide a stronger infiltration, strategy to ensure that targeted specific genes steadily and more efficiently, improved digestion resistance, cheaper price, and greater ability for transporting DNA than alternative non-viral methods of gene transfer when subjected to a magnetic field from the outside [28]. Adenovirus, adeno-associated virus, poxvirus, herpes simplex virus are the common non-viral vectors are currently being used. As a result, both viral and non-viral vectors are changed to fit various therapeutic systems, and the clinical trial's safety and efficiency are assessed [29]. Superparamagnetic NPs are used to deliver the genes inside the somatic cells of mammals, which might be utilized as a somatic cell nuclear transfer methodology for the reproductive cloning system. Magnetofection utilized the magnetic force to encourage the absorption of gene vectors containing cationic magnetic NPS by specific receptors, which gene transfer approach is extremely efficient **[28].** MNPs are coupled to the reporter or therapeutic genes, which are high-gradient magnets aimed at the targeted cells. Magnetofection techniques dramatically decrease the transfection time, when compared to other non-viral agents. The gene is affixed to the MPs or carrier directly in the magnetic drug delivery of magnetofection. Small interfering RNA (siRNA) has been successfully delivered using this method in vitro and in vivo antisense oligonucleotides [30]. The combination of polyethylenimine (PEI) and polyacrylic acid (PAA) with surface-modified superparamagnetic iron oxide nanoparticles (SPIONs- PEI- PAA) proved the magnetofection of cells and tumors in mice was found to be both effective and safe. SPIONs- PEI- PAA with reporter gene encoded via plasmid DNA was more effective at transfection [31]. Currently, viral vectors such as retroviruses and adenoviruses, nucleic acid electroporation, and nucleic acid transfection are used in three primary gene delivery techniques. The iron oxide-based MNPs could be a useful tool in the development of next-generation medicines as a non-viral gene delivery system, which has demonstrated excellent efficiency and low cytotoxicity when delivering nucleic acids into living cells [32].

MNPs can be utilized to distribute many types of nucleic acids after being functionalized with nucleic acid carriers. MNPs are being studied for use in a variety of gene therapy systems. Such as,

a. Prostate cancer gene therapy based on siRNA

SiRNA based Gene Therapy strategies have been developed in recent years. It has been used for gene silencing to limit cellular function against a variety of genes. SiRNA delivered specifically to cells relating to a particular target could silence genes in those cells.

b. Prostate cancer gene therapy based on CRISPR/Cas9

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) was discovered invading genomic material and operating as an adaptive immune response system for associated (Cas) nucleases. CRISPR, on the other hand, is frequently used for numerous applications of gene expression regulation because of its DNA-targeting technique that is extremely effective. Researchers have used the method to tweak and develop new therapies for a variety of disorders by inhibiting some targeted genes. The main issue is the system's ability to deliver safely and efficiently. To tackle this challenge, "chimera" was being developed as a combination of drug delivery and targeting.

c. Prostate cancer gene therapy based on P DNA

Some scientists have experimented with delivering plasmid DNA (P DNA) into tumor cells, particularly prostate cancer cells. One of the experiments involves modifying MNPs with low molecular weight linear PEI and developing a novel DNA delivery vehicle and transfection agent. These MNPs are easily controlled by external magnetic force. These system properties are widely used in Gene Therapy applications because PDNA has specific properties such as [29],

1. Prevent the DNA from Degradation
2. Excellent biocompatibility
3. Excellent DNA loading capacity
4. Lower toxicity
5. Higher DNA binding capacity

d. Prostate cancer gene therapy based on MiRNA

MiRNA is a very small, single, no coding molecule The role of MiRNA in prostate cancer gene therapy has been examined by a number of researchers. In one study, For the distribution of MiR-145 to prostate cancer, polyarginine peptide (R11) has been attached to PEI nanoparticles.

e. Gene therapy based on Aptamer

The aptamer technique is used to specifically PSMA receptors are targeted in cells of prostate cancer, and it is coupled to NPs for distribution. MRI has been used in a variety of studies for cancer diagnosis and medicine administration to specific tissues or cells. In one study the Aptamer combine with MNPs ($Fe_3O_4$). These MNPs are good biocompatibility and lower toxicity.

Wang Y et.al designed a multiple genes delivery system utilizing positively charged polyethylenimine (PEI) polymers-coated superparamagnetic $Fe_3O_4$ magnetic NPs with magnetism as gene carriers into the nuclei of swine somatic cells for porcine kidney cells, which can easily be used, robust, biocompatibility and targeted delivery. The spherical magnetic $Fe_3O_4$ NPs demonstrated excellent binding capacity for DNA due to the strong electrostatic interactions of positively charged polyethylenimine (PEI) coated $Fe_3O_4$ NPs with

negatively charged DNA to produce MNP-DNA complexes, which complexes after being introduced into cells, the DNA is protected against nuclease destruction. Where plasmid carries the genes encoding a green or red fluorescent protein after surface modification with polyethylenimine. These superparamagnetic NP-DNA complexes react to a magnetic pull from the outside, which accelerates the gene's targeting and deposition on the surface of the cell and lowers the time it takes to transfect a cell. As a result, cellular endocytosis of DNA is boosted, and exogenous gene expression efficiency is improved [28].

Magnetofection of cells from several cell lines with pDNAIL12 or pDNAGFP by utilizing SPIONs- PEI-PAA was carried out by Sara Prijic et.al. They were made the comparison to commercially available MNPs for transfection efficacy and two well-known non-viral transfection methods such as lipofection and electroporation. The development of membrane disruptive agents by using coating and functionalization of SPIONs with pH-responsive endosomolytic polymers PAA and PEI was proved that the vitro magnetofection of various cells with pDNA expressing either GFP or IL-12 is safe, effective, and superior to various other non-viral transfection techniques in terms of transfection efficiency. Sara Prijic et.al proved that the significant antitumor effect resulted that SPIONs- PEI- PAA being used to magnetofect breast adenocarcinoma TS/A tumors with pDNA encoding IL-12 [31].

## 7. BACTERIAL THERANOSTICS

Recently, MNP-based approaches for treating infections caused by multidrug-resistant bacteria and biofilm-related pathogens have recently been developed. MNPs kill bacteria by causing damage to plasma membranes, creating reactive oxygen species (ROS) and releasing poisonous metals, all of which cause critical bacterial components to malfunction. Biofilms that adhesion to surfaces are a type of bacterial community. Because biofilm is confined in a self-releasing matrix of extracellular polymeric substances (EPS), where traditional antibiotics are ineffective in treating this infection. The prescription of treatment is frequently influenced by the length of the testing process and the time it takes for individuals to respond. To overcome these constraints, improved strategies such as ELISA (enzyme-linked immunoassay), whole-genome sequencing, Western blotting, and PCR (polymerase chain reaction) were developed to speed up detection and provide more precise information about microorganisms. The MNPs improved a variety of sensing techniques, including colorimetric detection, PCR, surface-enhanced Raman detection, and fluorescence detection making them as systems for bacterial detection that seem promising. [2].

## 8. BIOSENSING

MNPs-based biosensors offer a wide range of applications in the biomedical area due to their compact size, high sensitivity, and fascinating noninvasive detection characteristic [2]. A biosensor is a device that can

convert a biological event into cells that can be detected easily. Although their surfaces could be readily customized with a number of receptors and they could also be used as ferromagnetic labels, they are becoming increasingly popular, MNPs are well suited for usage as biosensor platforms. Tagging sensor supports and transducer materials are examples of sensing applications of MNPs. materials [33].Different biosensors are primarily capable of detecting various biological molecules [8]. Au NPs utilized for colorimetric detection because of their easy surface modification, good solubility, and excellent biocompatibility. The MNPs with Au NPs allow for bacterial aggregation and separation, allowing for a more sensitive colorimetric detection effect due to the bacterial aggregation via a change in concentration from low to high while increasing the sensitivity of detection [34]. The glucose sensor made from pyrrole chemical oxidative polymerization on ZnFe2O4 nanoparticles worked effectively. They have a high sensitivity to glucose detection [35]. The glucose in plasma samples was determined using the biosensor that had been developed. Nouira et al. used gold and MNPs, one glucose conductometric biosensor was created. A glucose oxidase coating on polyallylamine hydrochloride, which was then placed on a planar interdigitated electrode, was used to modify the two types of nanoparticles [36]. To detect chloramphenicol, a new fluorescent biosensor based on aptamer was created. The fluorescence biosensor uses aptamer-conjugated MNPs for recognition and concentration elements. Upconversion nanoparticles were utilized as highly sensitive signal markers in the biosensor. The constructed biosensor was stable, sensitive, and easy providing it a major edge in nano-label bioassays [37].

The review of Xiang et.al, covers the latest research on MNPs in bacterial detection and treatment. Different metals and metal oxide NPs have been utilized to overcome the limitations of traditional antimicrobial treatment and detection methods. MNPs could also attach to certain materials, allowing them to be used for bacterial separation and enrichment [34].

## CONCLUSION

Due to their special properties, they are widely used and are being further tested in various applications in the bio-medical sector. The ability to make multipurpose treatment substances and to focus nanoparticles to specific locations are the future of magnetic nanoparticle applications. The current research on MNP MRI, drug carriers, treatment for cancer, hard tissue repair, tissue regeneration, biosensors, and other biomedical applications as well as the results of those tests, are described in this review. They also present the challenges of using them. Magnetic nanoparticles with advanced uses for treating a variety of illnesses could be possible soon. Because of new understanding of how magnetic nanoparticles interact with the human body, everything from mending tissues to eliminating cancer cells to infection prevention has been improved.

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