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Nanomedicine And Cancer Treatment: Review the Latest Developments in Using Nanotechnology for Cancer Diagnosis, Imaging, And Therapy.

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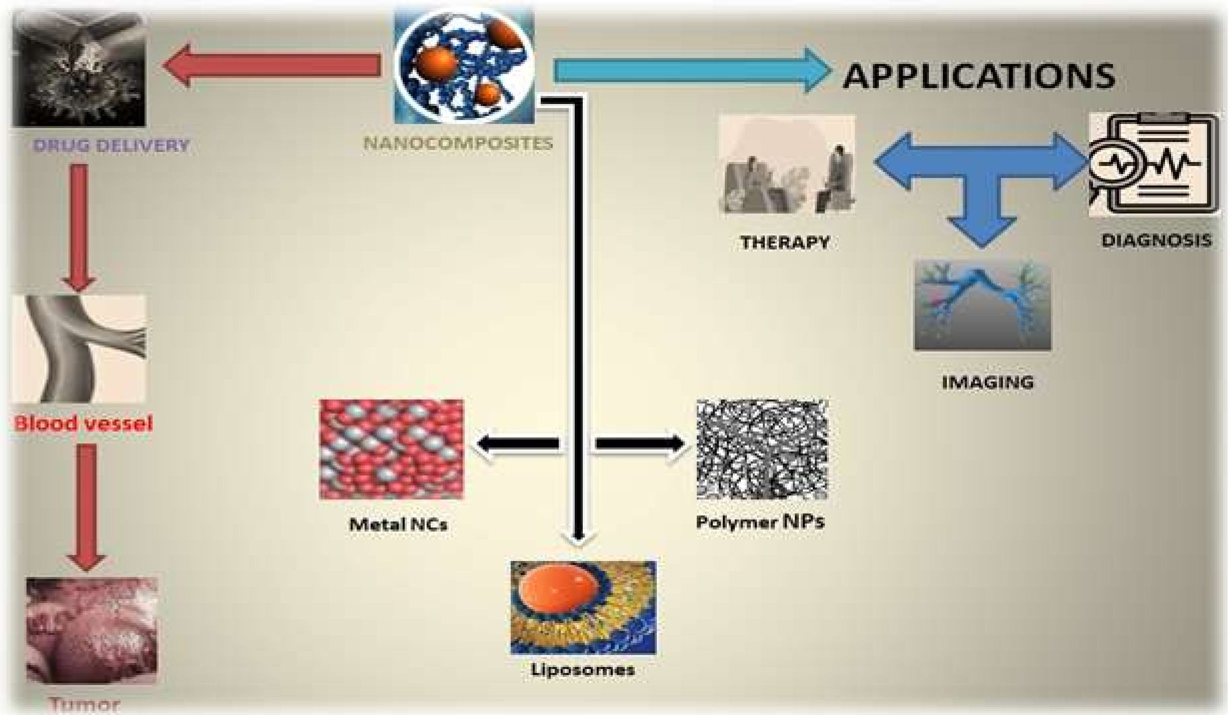
ABSTRACT

Background: Nanoparticles have potential for creating sophisticated medication delivery system. These systems could improve interaction with biological membranes and enable selective drug delivery to specific cells, facilitating targeted and personalized treatment. Nanomedicine has become a hopeful frontier in cancer research, providing creative solutions to diagnosis, imaging, and therapy. This review explores recent advancements in nanotechnology applications for oncology.

Main body of the extract: In cancer diagnosis, nanoparticle based biosensors have demonstrated enhanced sensitivity and specificity for detecting tumor markers in blood and tissue samples. Novel quantum dot probes and nanoparticle contrast agents have improved the resolving power and accuracy for imaging cancers technique, leading to improved diagnostic early detection and more precise tumor localization. Therapeutic applications of nanomedicine have shown particular promise, with nanocarriers target therapeutic payloads to tumor locations while sparing systemic toxicity. Smart nanoparticles responsive to tumor microenvironments have been developed to release payloads selectively within cancer cells. Additionally, nanoparticle-mediated photodynamic and photothermal therapies have shown efficacy in destroying tumor tissue with minimal damage to healthy cells. Challenges remain in optimizing nanoparticle design, enhancing tumor penetration, and addressing potential long-term toxicity concerns.

Conclusion: The integration of nanotechnology in cancer management offers significant potential for improving patient outcomes through more accurate diagnosis, enhanced imaging capabilities, and targeted therapeutic interventions.

Graphical abstract:



Background:

Nanomedicine has emerged as a groundbreaking field at the nexus of nanotechnology and medicine, offering unparalleled possibilities for revolutionizing cancer diagnosis, imaging, and treatment [1]. With a greater understanding of cancer biology and advances in nanotechnology, researchers are developing innovative approaches to combat this complex disease at the molecular level [2]. This review explores the latest developments in nanomedicine for cancer management, highlighting how these tiny particles are making a big impact in oncology [3]. Nanoparticles, which are typically 1 to 100 nanometers in size, have special properties that make them valuable in cancer applications. Their size allows them to maneuver throughout the body and interact with cancer cells in ways that traditional therapies cannot [4,5]. Moreover, they can be engineered to perform various functions simultaneously, they are targeted drug delivery, enhanced imaging and in the body monitors of treatment efficacy. Recent advancements in nanomedicine have led to improved cancer diagnostics, more precise imaging techniques, and novel therapeutic strategies. From early detection of tumors to personalized treatment plans, nanotechnology is transforming every aspect of cancer care. This review will delve into the cutting edge developments in nanoparticle-based cancer diagnosis, including liquid biopsies and molecular imaging [6,7]. We will also explore how nanoparticles are enhancing current cancer therapies and how they are advancing new treatment paradigms such as photothermal therapy and gene therapy. As we examine these exciting developments, we should also consider the challenges and prospects for future development of nanomedicine in cancer therapy. While many nanoparticle-based therapies show promise in preclinical studies, translating these findings into practice such as safety, scalability and regulatory issues [8,9]. However, the prospects of nanomedicine transforming cancer care are tremendous and overall, represent a substantial promise for more effective, less invasive and individualized treatment options for cancer patients, globally [10].

Main text

Nanoparticles- Controlled release and targeted medicine delivery

Drug delivery methods based on nanoparticles have become a viable strategy to raise the effectiveness and safety of medicinal substances. Compared to traditional drug formulations, these systems have a number of benefits, such as improved bioavailability, controlled release, and targeted delivery [11,12]. One of the main advantages of nanoparticle-based systems is targeted drug delivery. By designing nanoparticles with specific surface modification or ligands, Drugs can be targeted to specific tissues, organs, or cell types by creating nanoparticles with particular surface modifications or ligands [13,14]. By reducing off-target effects and enabling lower drug dosages, this targeting capability may help minimize side effects. For instance, chemotherapeutic agents can be delivered directly to tumors while preserving healthy tissues by engineering nanoparticles to recognize and bind to cancer cells [15]. Another crucial component of drug delivery systems based on nanoparticles is controlled release mechanisms. These processes enable medications to be released gradually and continuously over time, sustaining therapeutic concentrations for prolonged periods of time [16,17]. This can be accomplished in a number of ways, including the use of stimuli-responsive nanoparticles, which release their payload in response to particular environmental cues like pH changes or enzyme activity, or biodegradable polymers, which gradually decompose to release the drug that is encapsulated. By lowering the frequency of doses and preserving ideal drug levels, controlled release can increase treatment effectiveness and patient compliance. Drug delivery systems based on nanoparticles can take advantage of the enhanced permeability and retention (EPR) effect, which is especially useful in the treatment of cancer [18]. Because tumor blood vessels are frequently ill-formed and leaky, nanoparticles can preferentially accumulate in tumor tissues. The retention of nanoparticles in the tumor microenvironment is further facilitated by the fact that tumors usually have inadequate lymphatic drainage. Nanoparticle-based systems can passively target tumors by utilizing the EPR effect, which lowers systemic exposure and increases drug concentration at the disease site. The following tactics can be used to improve drug delivery systems based on nanoparticles: 1. Surface modification: Applying coatings such as polyethylene glycol (PEG) to nanoparticles can lengthen their bloodstream circulation time and increase the likelihood that they will reach their target location. 2. Optimization of size and shape: Nanoparticles' biodistribution and cellular uptake can be strongly impacted by their size and shape. 3. Stimuli-responsive designs: Creating nanoparticles that react to internal cues (like pH shifts or enzyme activity) or external stimuli (like light, magnetic fields, or ultrasound) can allow for more accurate control over drug release. 4. Combination therapies: Drug resistance may be overcome and synergistic effects may be achieved by designing nanoparticles to carry several medications or therapeutic agents. 5. Theranostic applications: Incorporating imaging agents into drug loaded nanoparticles enables simultaneous diagnosis and treatment, facilitating personalized medicine approaches [19,20].

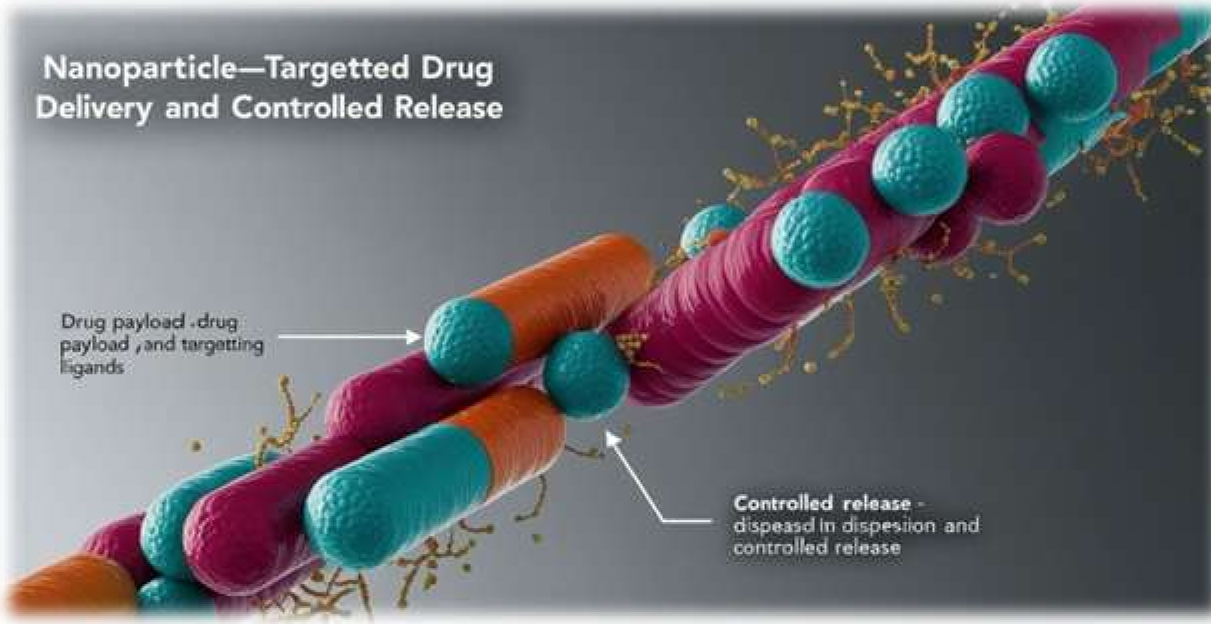


Fig. 1
Nanoparticles- Controlled release and targeted medicine delivery (created by Canva)

Nanotheranostics: Integrated diagnosis and therapy

Nanotheranostics is an exciting and rapidly advancing field that combines diagnostic imaging with therapeutic capabilities in a single nanoparticle platform. Combining diagnosis and therapy: The ability to simultaneously diagnose and treat diseases, especially cancer, is the main benefit of Nanotechnology [21,22]. With this method, real-time imaging feedback can be used to customize treatment, enabling personalized medicine. By integrating diagnostic and therapeutic functions, nanotheranostic agents can help monitor drug delivery, assess treatment efficacy, and guide further therapeutic decisions. Multimodal imaging agents: Developing nanoparticles that can be detected by multiple imaging modalities enhances their diagnostic capabilities. For example, combining positron emission tomography (PET) or optical imaging with magnetic resonance imaging (MRI)
can provide complementary information about disease progression and treatment response [23,24]. Thus multimodal approaches enable more accurate diagnosis and better therapy. Some strategies for creating multimodal imaging agents include: - Incorporating different contrast agents within a single nanoparticle. Designing nanoparticles with inherent properties suitable for multiple imaging techniques. Attaching targeting ligands to improve specificity and enhance contrast Theranostic nanoparticles for simultaneous imaging and treatment: The purpose of nanoparticles is to carry both agents for imaging and therapeutic payloads [25,26]. Some approaches include: Photodynamic therapy: Light activated nanoparticles that provide fluorescence imaging and produce reactive oxygen species for the treatment of cancer Photothermal therapy: Plasmonic nanoparticles that can generate heat for tumor ablation and serve as contrast agents for imaging Drug delivery: Nanocarriers loaded with both imaging agents and chemotherapy medications to monitor drug release and accumulation in target tissues. Gene therapy: Nanoparticles carrying genetic material for therapeutic purposes along with imaging capabilities to track their delivery and expression [27,28]. To optimize theranostic nanoparticles, consider: - Biocompatibility and biodegradability to ensure safety. Targeting strategies to improve accumulation in diseased tissues Stimuli responsive designs for controlled drug release. Optimizing size and surface properties for enhanced circulation and tissue penetration Future directions and challenges:- Enhancing the sensitivity and specificity of imaging and therapeutic processes by creating "smart" nanoparticles that may change their characteristics in response to the biological environment. Addressing potential toxicity concerns and regulatory hurdles - Scaling up production for clinical translation Exploring applications beyond cancer, such as cardiovascular diseases and neurodegenerative disorders [29,30].

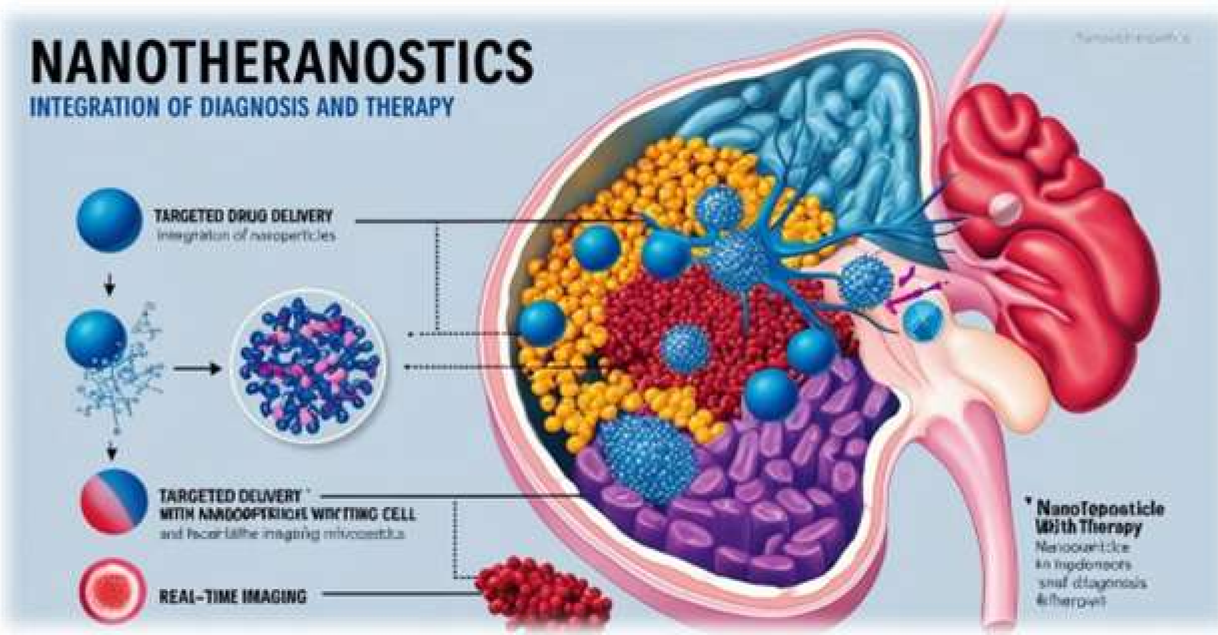


Fig. 2 Nanotheranostics: Integrated diagnosis and therapy **(**Created by Canva**)**

Nano-Enabled Tumor Detection and Liquid Biopsy

With its novel methods for identifying and analyzing cancer in its early stages, nanotechnology has become a potent tool in the diagnosis of the disease. Nanotechnology applications in cancer diagnosis, focusing on nanoparticle based biosensors, circulating tumor cell detection, and liquid biopsy techniques [31]. Nanoparticle based biosensors: Because they can detect cancer biomarkers with high sensitivity and specificity, nanoparticle-based biosensors have completely changed the way that cancer is diagnosed [32]. These biosensors can be designed to target particular cancer-associated molecules, proteins, or genetic markers. Some key ideas in this area include: - Utilizing quantum dots as fluorescent labels for multiplexed detection of multiple cancer biomarkers simultaneously. Developing plasmonic nanoparticles for Raman spectroscopy with surface enhancement to detect cancer-specific molecular signatures. Making magnetic nanoparticles functionalized with aptamers or antibodies to extract and concentrate cancer biomarkers from intricate biological materials .Exploring the use of carbon nanotubes or graphene-based sensors for electrical or electrochemical detection of cancer markers [33]. To improve the effectiveness of nanoparticle-based biosensors, researchers should focus on enhancing their stability in biological fluids, increasing their sensitivity and specificity, and developing user-friendly platforms for point-of-care diagnostics [34]. Circulating tumor cell detection: Nanotechnology has greatly improved the detection and separation of circulating tumor cells (CTCs) from blood samples, providing valuable information for cancer diagnosis and monitoring [35,36]. Some promising approaches include: - Designing nanostructured surfaces or microfluidic devices with nano-scale features to capture CTCs based on their size, shape, or surface properties - Using magnetic nanoparticles conjugated with cancer-specific antibodies to isolate CTCs from blood samples Creating contrast agents based on nanoparticles for CTC tracking and in vivo imaging Creating nanoscale sensors in order to keep an eye on CTC levels within the bloodstream To advance CTC detection techniques, researchers should focus on improving the capture efficiency and purity of isolated CTCs, developing methods for downstream analysis of captured cells, and exploring ways to differentiate between various CTC subpopulations [37,38]. Nanotechnology-based liquid biopsy techniques: Nanotechnology has been instrumental in improving the capabilities of liquid biopsy, which has become a minimally invasive method for cancer diagnosis and monitoring. Some innovative ideas in this field include: - Extracting and enriching circulating tumor DNA (ctDNA) from blood samples using nanoparticles. Developing nanoscale sensors for the detection of cancer-specific exosomes or extracellular vesicles. Developing assays based on nanoparticles to identify circulating microRNAs linked to cancer. Exploring the use of nanopore technology for single-molecule sequencing of ctDNA or other cancer-related nucleic acids [39,40].

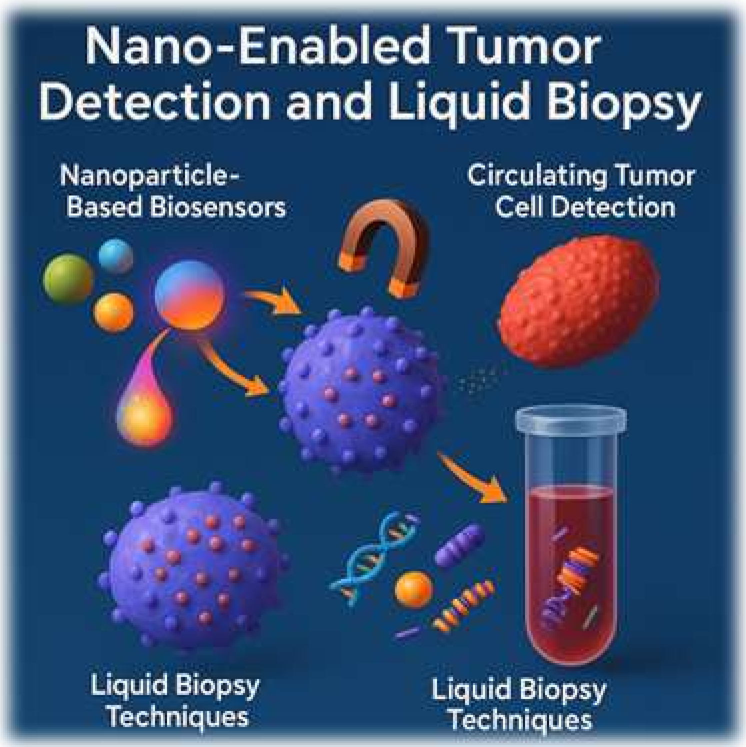


Fig. 3 Nanotheranostics: Integrated diagnosis and therapy

Nanoparticle Driven Advanced Imaging

Advanced imaging techniques using nanoparticles have revolutionized medical diagnostics and research by offering enhanced contrast, sensitivity, and specificity [41]. Various nanoparticle-based imaging modalities: Nanoparticles as MRI contrast agents have greatly enhanced diagnostic precision and image quality in magnetic resonance imaging (MRI) [42]. Because they can reduce T2 relaxation times and provide negative contrast enhancement, superparamagnetic iron oxide nanoparticles, or SPIONs, are used extensively. Targeting ligands can be added to these nanoparticles to functionalize them for imaging of particular tissues or organs. Gadolinium-based nanoparticles are another popular choice for T1-weighted imaging, offering positive contrast enhancement [43,44]. However, researchers are exploring alternatives to address concerns about gadolinium toxicity. To optimize MRI contrast agents, consider: - Tailoring nanoparticle size and shape for improved circulation time and tissue penetration. Developing multimodal nanoparticles that combine MRI contrast with other imaging modalities. Exploring stimuli responsive nanoparticles that can be activated in specific physiological conditions Optical Imaging Probes: Nanoparticles have greatly enhanced optical imaging methods, especially in the area of fluorescence imaging [45,46]. Compared to conventional organic dyes, quantum dots (QDs), semiconductor nanocrystals, provide better brightness, photostability, and adjustable emission wavelengths. Gold nanoparticles offer highly sensitive and multiplexed biomolecule detection, making them ideal for surface-enhanced Raman spectroscopy (SERS) imaging. Tips for optical imaging probes: - Use near-infrared (NIR) emitting nanoparticles to achieve deeper tissue penetration. Create activatable probes that only glow when particular enzymes or environmental factors are present. Investigate upconversion nanoparticles to enhance signal-to-noise ratios and decrease autofluorescence. Photoacoustic Imaging: This technique combines the deep tissue penetration of ultrasound with the high contrast of optical imaging. Nanoparticles are essential in improving photoacoustic signal generation and specificity [47,48]. Gold nanostructures, such as nanorods and nanoshells, are popular for photoacoustic imaging because of their high NIR optical absorption. Nanoparticles made of carbon such as carbon nanotubes and graphene oxide, are also effective photoacoustic contrast agents. To improve imaging using photoacoustics with nanoparticles: - Optimize nanoparticle size and shape for maximum light absorption and heat generation. Develop biodegradable photoacoustic contrast agents for improved safety and clearance . Examine how certain biological cues can cause stimuli. responsive nanoparticles to alter their photoacoustic signal. General advice for imaging using nanoparticles: - Consider the biodistribution and pharmacokinetics of nanoparticles when designing imaging probes .Optimize surface chemistry and coating to improve stability, biocompatibility, and targeting efficiency. Explore theranostic nanoparticles that combine imaging capabilities with therapeutic functions Investigate multimodal imaging nanoparticles to leverage the strengths of different imaging techniques.Address potential toxicity and long-term safety concerns associated with nanoparticle based contrast agents [49,50].

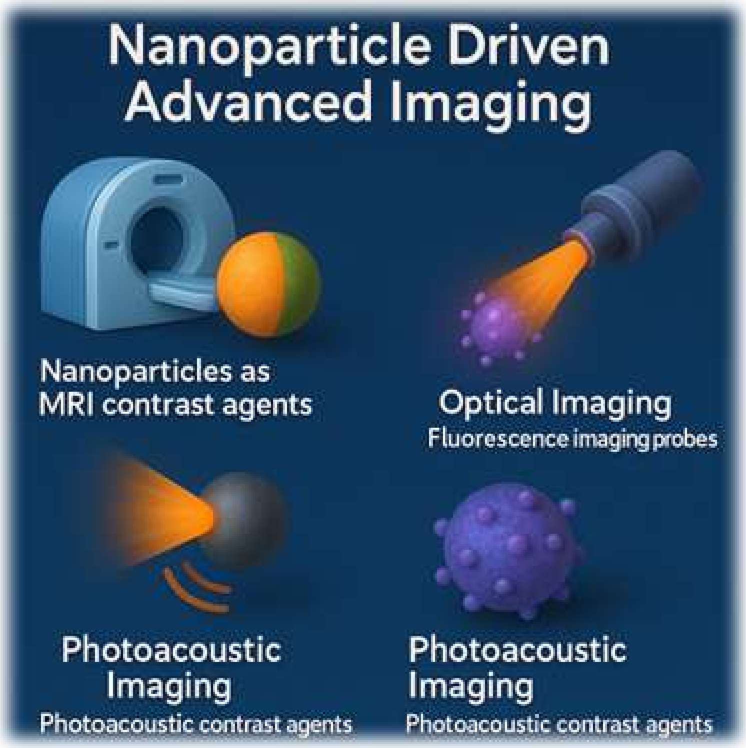


Fig. 4 Nanoparticle Driven Advanced Imaging

Nanoparticle Based Cancer therapies

Nanoparticle-mediated cancer therapies represent a promising frontier in oncology, offering targeted and minimally invasive treatment options. Three particularly exciting approaches in this field are photothermal therapy, photodynamic therapy, and magnetic hyperthermia. Let's explore some ideas and tips for each of these therapies [51,52]. Photothermal Therapy: Photothermal therapy utilizes nanoparticles that can transform light into heat, raising the temperature locally in order to kill cancer cells. Some key ideas and tips for this therapy include: - Choosing nanoparticles like carbon nanotubes or gold nanorods that have the best light-absorbing qualities. Tailoring the nanoparticle surface to improve tumor targeting and cellular uptake. Optimizing the light source (e.g., near-infrared lasers) for maximum tissue penetration and minimal damage to healthy cells Using photothermal therapy in conjunction with immunotherapy or chemotherapy to achieve synergistic effects. Developing real time temperature monitoring systems to ensure effective and safe treatment Photodynamic Therapy: Photodynamic therapy involves using light sensitive compounds called photosensitizers, which generate species of reactive oxygen to destroy malignant cells when light activates them [53,54]. Some ideas and tips for enhancing this approach include: - Engineering nanoparticles to encapsulate and deliver photosensitizers more effectively to tumor sites Exploring two photon excitation techniques to achieve deeper tissue penetration Investigating oxygen independent photosensitizers to overcome the limitations of hypoxic tumor environments. Combining photodynamic therapy with antiangiogenic agents to enhance treatment efficacy. Creating light sources that can be implanted to treat deep-seated tumors When exposed to an alternating magnetic field, magnetic nanoparticles produce heat, which causes cancer cells to die. This phenomenon is known as magnetic hyperthermia [55,56]. Some ideas and tips for improving this therapy include: - Optimizing nanoparticle composition and size for maximum heating efficiency. Developing targeted delivery strategies to increase nanoparticle accumulation in tumors. Exploring multimodal nanoparticles that combine magnetic properties with imaging capabilities for theranostic applications. Investigating the potential of magnetic hyperthermia to enhance drug delivery and overcome multidrug resistance. Designing more efficient and compact magnetic field generators for clinical use General tips for advancing nanoparticle-mediated cancer therapies: - Concentrate on enhancing tumor accumulation and nanoparticle biodistribution using active targeting techniques and the enhanced permeability and retention (EPR) effect [57,58]. Examine the possibility of using stimuli-responsive nanoparticles to release therapeutic agents in a controlled manner. Develop strategies In order to get past biological obstacles like the blood-brain barrier, for treating challenging cancer types. Examine how machine learning and artificial intelligence can be used to improve treatment planning and predict patient responses Conduct comprehensive toxicity studies to ensure the durability of treatments based on nanoparticles .Work together across fields such as clinical oncology, biology, and materials science to expedite the transition of these treatments from the bench to the bedside [59,60].

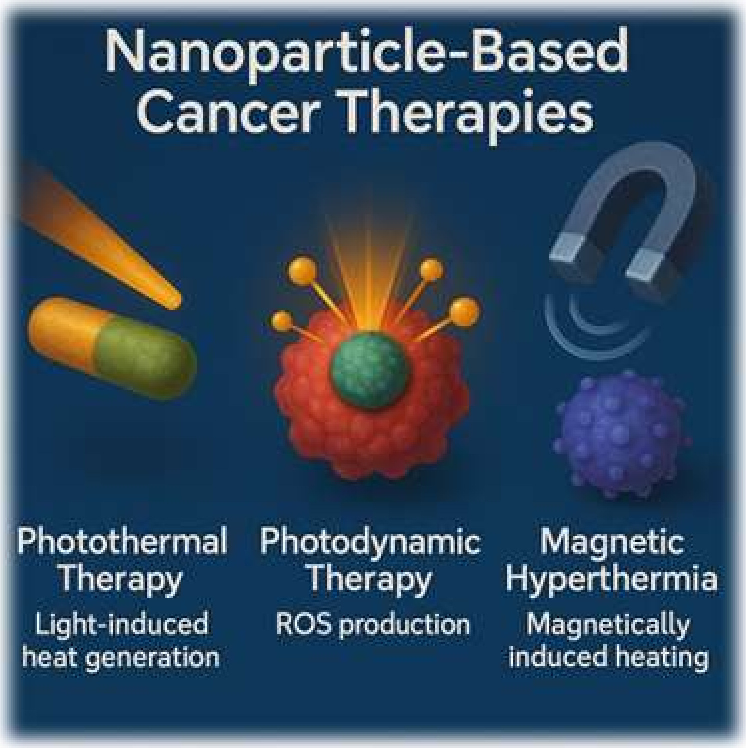


Fig. 5 Nanoparticle Based Cancer therapies

Nanocarrier- Based Gene therapy and RNA interference

Gene therapy and RNA interference using nanocarriers have emerged as promising approaches for treating various genetic disorders and diseases. siRNA delivery and CRISPR-Cas9 delivery for gene editing: siRNA Delivery: 1. Lipid nanoparticles: Utilize lipid-based nanocarriers to encapsulate siRNA molecules, protecting them from degradation and enhancing cellular uptake. 2. Polymer-based nanocarriers: Develop biodegradable polymeric nanoparticles to deliver siRNA, allowing for controlled release and improved stability. 3. Targeted delivery: Functionalize nanocarriers with ligands or antibodies to achieve cell-specific targeting, increasing the efficiency of siRNA delivery to desired tissues. 4. Endosomal escape: Incorporate pH-sensitive materials or fusogenic peptides into nanocarriers to facilitate endosomal escape and cytoplasmic release of siRNA. 5. Combination therapy: To improve treatment effectiveness and combat drug resistance, co-deliver siRNA with small molecule medications or other therapeutic agents [61,62,63,64]. Delivery of CRISPR-Cas9: 1. Viral vectors: Utilize adeno-associated viruses (AAVs) or lentiviruses as efficient delivery vehicles for CRISPR-Cas9 components, especially for in vivo applications. 2. Lipid nanoparticles: Develop lipid-based nanocarriers to encapsulate CRISPR-Cas9 components, protecting them from enhancing cellular uptake and reducing degradation. 3. Gold nanoparticles: Explore the use of gold nanoparticles as carriers for CRISPR-Cas9 components, leveraging their unique properties for enhanced delivery and gene editing efficiency. 4. Cell-penetrating peptides: Conjugate cell-penetrating peptides to CRISPR-Cas9 components to facilitate their cellular uptake and nuclear localization. 5. Exosome-based delivery: Harness the natural ability of exosomes to cross biological barriers for efficient delivery of CRISPR-Cas9 components [65,66,67]. General tips for both approaches: 1. Optimize nanocarrier dimensions and surface characteristics to improve cellular uptake and prevent the immune system from clearing you quickly. 2. Consider the route of administration (e.g., intravenous, intratumoral, or inhalation) when designing nanocarriers for specific applications. 3. Evaluate the potential for off-target consequences and develop methods to reduce them, such as using tissue-specific promoters or chemically modified guide RNAs. 4. Investigate Utilizing stimuli-responsive nanocarriers can release their payload in response to specific triggers (e.g., pH, temperature, or light). 5. Examine the possibility of achieving synergistic effects by combining gene therapy techniques with other therapeutic modalities, such as immunotherapy or chemotherapy. 6. Consider the scalability and manufacturability of nanocarrier formulations to ensure their potential for clinical translation. 7. Develop strategies In order to get past biological obstacles like the tumor microenvironment or the blood-brain barrier, to improve the delivery of medicinal substances to target tissues. 8. Investigate the long-term effectiveness and safety of nanocarrier-based gene therapy approaches through comprehensive preclinical studies. 9. Investigate non-viral delivery methods to enhance the possibility of repeated administration and allay safety worries related to viral vectors. 10. Optimize the ratio of therapeutic components (e.g., siRNA or CRISPR-Cas9) to nanocarrier materials to achieve maximum efficacy while minimizing potential toxicity [68,69,70].

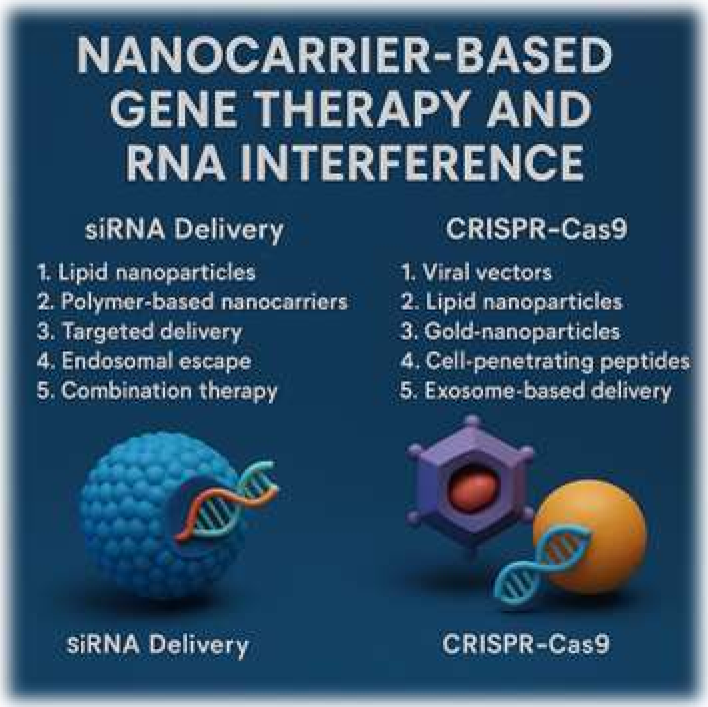


Fig. 6 Nanocarrier- Based Gene therapy and RNA interference

Nanoparticle- Enhanced Immunotherapy

Immunotherapy and nanoparticles represent an exciting frontier in cancer treatment, offering promising avenues for enhancing the body's natural defenses against tumors. Here are some ideas and tips on nanoparticle-based cancer vaccines and immune checkpoint inhibitor delivery: Nanoparticle-based cancer vaccines: It is possible to engineer nanoparticles to effectively delivery antigens for cancer to the immune system, stimulating a more robust anti-tumor response [71,72]. Certain immune cells, like dendritic cells, which are essential for starting and guiding immune responses, can be targeted by these nanoparticles. One approach is to create nanoparticles that encapsulate tumor-specific antigens along with immunostimulatory molecules. Compared to conventional vaccination methods, this combination can help overcome immune tolerance and activate tumor-specific T cells more successfully. Another strategy involves using nanoparticles to deliver mRNA encoding tumor antigens. This approach allows for the production of antigens directly within the patient's cells, possibly resulting in a more effective and varied immune response [73,74]. Additionally, nanoparticles can be made to resemble viruses in structure, which can increase immune cells' absorption of the particles and boost the effectiveness of the vaccine as a whole. By adjusting the size, shape, and surface properties of nanoparticles, Researchers can maximize their capacity to access lymph nodes, where they can interact with a high concentration of immune cells and initiate a strong anti-tumor response [75,76]. Immune checkpoint inhibitor delivery: Nanoparticles offer a promising approach to improve the effectiveness and delivery of immune inhibitors of checkpoints, which have revolutionized tumour treatment in recent years. One strategy involves encapsulating checkpoint inhibitors within nanoparticles to improve their pharmacokinetics and biodistribution. This can help increases the concentration of the drug at the tumor site while reducing systemic side effects. It is possible to design nanoparticles to co-deliver checkpoint inhibitors with other immunomodulatory agents, potentially synergizing their effects and overcoming resistance mechanisms. Researchers can develop systems that release checkpoint inhibitors in response to particular triggers within the tumor microenvironment, such as pH shifts or the presence of particular enzymes, by employing stimuli-responsive nanoparticles. To increase the overall effectiveness of checkpoint inhibition, nanoparticles can also be designed to target particular cell types found in the tumor microenvironment, such as myeloid derived suppressor cells or regulatory T cells. Another approach involves using nanoparticles to deliver checkpoint inhibitors directly to tumor-draining lymph nodes, where they can modulate T cell responses more effectively [77,78]. Combining nanoparticle-based delivery of checkpoint inhibitors with additional forms of therapy, such as radiation therapy or chemotherapy, may result in synergistic impacts and improved overall treatment outcomes. These approaches highlight the potential of strategies based on nanoparticles to enhance both cancer vaccines and immune checkpoint inhibitor therapies [79,80].

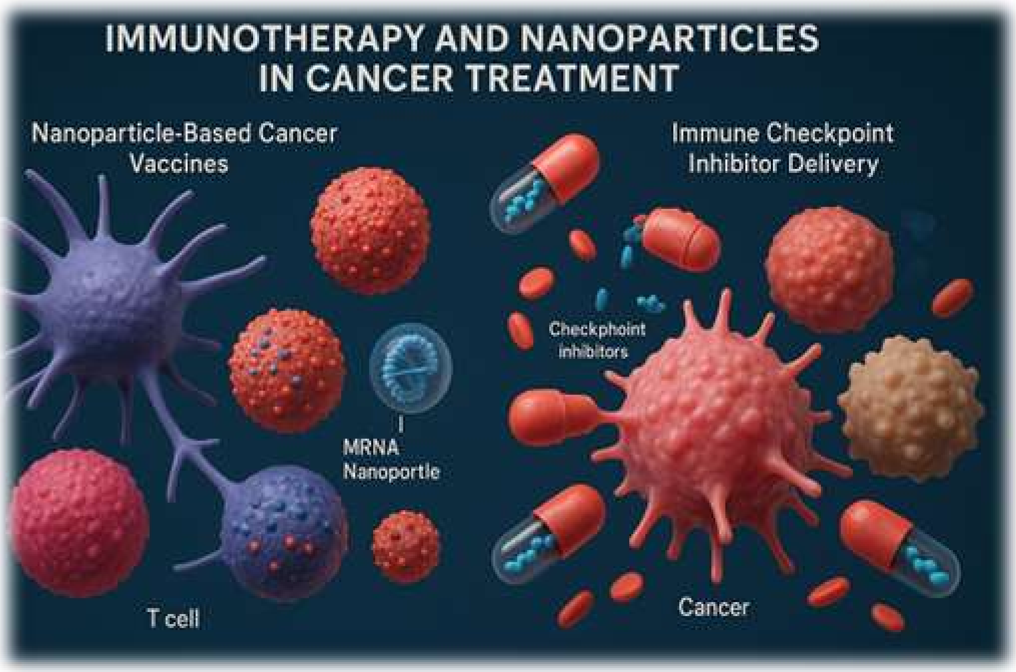


Fig. 7 Nanoparticle- Enhanced Immunotherapy

CONCLUSION

Nanomedicine has demonstrated tremendous potential in revolutionizing cancer care and other areas of medicine, offering innovative solutions for diagnostics, imaging, and therapy through the unique capabilities of nanoparticles. Advancements in targeted drug delivery systems, theranostic platforms, and nanoparticle-enhanced diagnostic techniques highlight the transformative possibilities of this field in achieving more accurate, efficient, and customized methods of providing medical care. While the field has made remarkable strides, There are still many obstacles in the way of implementing these advancements in clinical settings. Issues such as safety, biocompatibility, regulatory hurdles, and cost-effective scalability require further attention and interdisciplinary collaboration. The integration of new technologies, such as AI, gene editing and stimuli-responsive systems, promises to accelerate the evolution and optimization of nanoparticle-based solutions. The progress in nanoparticle enabled treatments like photothermal therapy, gene delivery, and immunotherapy reflects the versatility of nanotechnology in dealing with difficult medical issues. Moreover, the potential of nanoparticles to integrate diagnostic and therapeutic functionalities in real-time is clearing the path for dynamic and adaptive methods of treatment, bringing the vision of precision medicine closer to reality. Moving forward, sustained innovation, robust preclinical-to-clinical pipelines, and strong partnerships between researchers, clinicians and regulatory bodies will be necessary to fully realize the promise of nanomedicine. As the field evolves, it holds the promise of not just revolutionizing the treatment of cancer also addressing a broader variety of illnesses, significantly enhancing patient results in life quality.

List of Abbreviations

AAVs	Adeno-associated viruses
CRISPR -Cas9	Clustered Regularly Interspaced Short Palindromic Repeats
CTCs	Circulating tumor cells
ctDNA	Circulating tumor DNA
EPR	Enhanced permeability and retention
MRI	Magnetic resonance imaging
NIR	Near-infrared
PEG	Polyethylene glycol
PET	Positron emission tomography
QDs	Quantum dots
SERS	Surface-enhanced Raman spectroscopy
siRNA	Small interfering RNA
SPIONs	Superparamagnetic iron oxide nanoparticles

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Both the author's have read the manuscript and given there consent for publication.

Availability of data and materials

All data generated or analyzed during this study or included in this published article.

Competing Interests

The authors declare no competing interests.

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Author contributions

The first draft of the manuscript was written and prepared by first author Mouna. A and second author edited and revised the manuscript. Both the author's read and approved the final manuscript

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