International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

Nanotechnology In Cancer Diagnosis and Therapy

Prashant Kumar, Alvira Atiq* Dhirendra Kumar, Anurag Singh, Saurabh Mishra[1], Monika

Dilip Kishore Mehrotra Institute of Pharmacy, Sitapur, U.P., 261001, India.
**Corresponding Author: Alvira Atiq*
Dilip Kishore Mehrotra Institute of Pharmacy, Sitapur, U.P., 261001, India.

Date of Submission: 12-06-2026 Date of Acceptance: 22-06-2026

ABSTRACT

Cancer is one of the leading causes of death in present times, increasing the need for innovative treatments and early diagnosis of the disease. Cancer is caused by uncontrolled cell growth. In the last few decades, many new drugs have been approved and many are under clinical trials to treat this deadly disease. Traditional therapeutics frequently lack precise targeting, leading to suboptimal drug concentrations and off-target systemic side effects. NPs possess exceptional properties, such as a large surface area, high volume proportion, and better targeting capabilities, and have attracted attention in multidisciplinary areas, making them the most promising materials for many biomedical applications, especially in treatment and diagnosis. Moreover, multifunctional nanoparticles facilitate simultaneous diagnosis and therapy of cancer. Cancer immunotherapy has also gained significant attention in the current scenario, which mostly relies on nanoparticle-based biological and vaccine delivery systems, along with the introduction of nano adjuvants as components of nano vaccines to enhance immunogenicity against cancer protection. Nanotechnology has been used for the early diagnosis and treatment of diseases. The field of nanotechnology is expanding rapidly and has many applications. In cancer cell recognition, monitoring intracellular cell changes and preventing infections help treat untreatable cancers. This review discusses the recent advantages, applications, and challenges of nanotechnology in cancer diagnosis and therapy. [1]

KEYWORDS: Nanotechnology, Cancer, Nanodevices, Diagnosis, Treatment, Nanoparticles (N.P.s), Toxicity, Targeted delivery, Cancer imaging (C.I.).

I. INTRODUCTION

Nanotechnology is a significant field in science that is used for the diagnosis and prevention of cancer. Nanotechnology is derived from the Greek word *Nanos*, meaning “dwarf” or “midget.” It is combined with technology to describe the manipulation of matter at the atomic and molecular levels. Nanotechnology is a rapidly expanding area of research that has led to the development of novel targeted drugs for delivery and monitoring of cancerous stages. Nanotechnology includes the nanoparticle nanoparticles and nano medicine which possess the ideal properties of strength conductivity, reactivity at the atomic molecular supramolecular level to create system and devices in range of 1–10 nm. Nanomedicine is a branch of science and technology that is used to diagnose, treat, and prevent diseases. This is helpful for pain management and improves health through nanosized molecules. Cancer is derived from the Latin word cancrum, meaning crab. When an abnormality in cell division occurs during proliferation, it is called cancer or abnormal cell growth. Nanotechnology is a promising field in science and technology that is helpful in the early detection of cancerous cells. It is helpful in targeted drug delivery and monitoring of cancer cells at every stage of the life cycle. Nanomaterials can easily move inside the body from one organ to another and effectively penetrate the targeted tissues. Nanoparticles can be conjugated with drug molecules to target diseased tissues, such as cancer cells, for diagnostic purposes. Nanoparticles are smaller than blood cells and are almost the same size as DNA. [2]

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

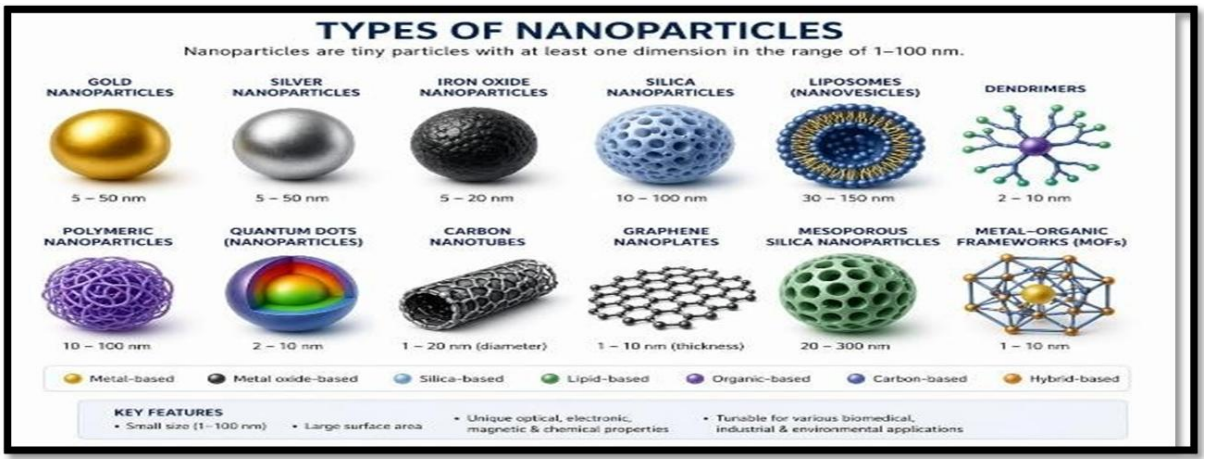

Fig.01- Types of Nanoparticles

Moreover, nanoparticles can function as targeting agents to target specific molecules in cancer cells for better cancer imaging, which can improve diagnosis. Nanoscale devices are a thousand times more microscopic than human cells and are comparable to biomolecules, such as enzymes and their respective receptors, in size. Biological processes that can lead to cancer also occur at the nanoscale level. Nanotechnology in cancer management has yielded various promising outcomes, including drug administration, gene therapy, monitoring and diagnostics, medication carriage, biomarker tracing, medicines, and histopathological imaging. [3]

2.1 Importance of Nanotechnology in cancer diagnosis of therapy

- In nanotechnology, a wide range of nanoparticles, including platinum-based quantum dots, liposomes, dendrimers fullerenes, polymeric-based nanoparticles, and nanoparticles, and meaning crab.
- When an abnormality in cell division occurs during proliferation, it is called cancer or abnormal cell growth.
- Nanotechnology is a promising field in science and technology that is helpful in the early detection of cancerous cells.
- It is helpful in targeted drug delivery and monitoring of cancer cells at every stage of the life cycle.
- In nanotechnology, a wide range of nanoparticles, including platinum-based quantum dots, liposomes, dendrimers fullerenes, polymeric-based nanoparticles, and many others, are used in cancer diagnosis and early detection and prevention of cancer.[4]

2.2 Advantages

→ Early detection of cancer cells
→ Treating various health condition of infectious diseases
→ Monitoring the cancerous stages
→ Targeted drug delivery

III. Nanoparticles in cancer diagnosis

- Nanoparticles are particles of matter or ultrafine particles ranging between 1 to 100 nanometres in diameter. Nanoparticles are the microscopic particles with wide variety of process physical, chemical &biological process
- Nanoparticles are sometimes used for larger particles up to 500 nm and tubes that are less than 100 nm.
- Nanomaterials or Nanoparticles play a significant role in existing drug therapy and diagnosis, in addition to various novel approaches to treat human malfunctioning.
- Nano-early cancer diagnosis helps solve the problem of people facing cancer.
- Various scanning techniques, such as X-ray, MRI, CT, and PET scans, are used for better imaging and detection.
- Any abnormal growth in tissues or cells helps confirm the disease.
- Application of nanotechnology in the diagnosis of extracellular biomarkers for cancer in vivo imaging.[5]

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

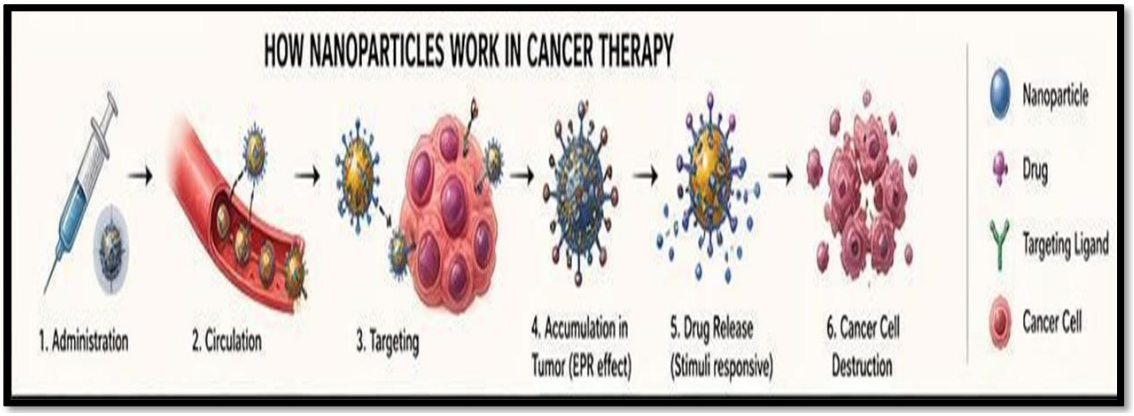

Fig.02- Working of Nanoparticles in Cancer Diagnosis

3.1 Liquid Biopsy

Nanotechnology promotes the non-invasive detection of circulating tumour DNA and cancer cells in blood samples, reducing the need for surgical biopsies. [6]

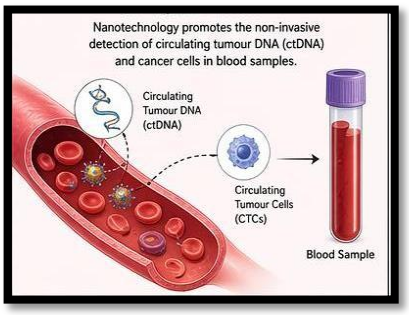

Fig.02- Liquid Biopsy

3.2 Imaging Techniques

Nanoparticles include MRI, CT scan, and PET scan by imaging cancerous cells and extending to various body areas. [7]

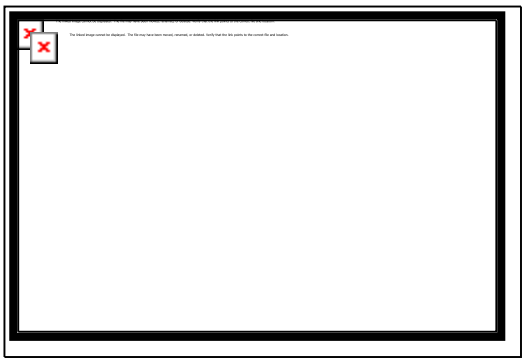

Fig.03- Imaging Techniques

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

3.3 Detection of Biomarkers

- Biomarkers are quantifiable indicators of normal biological function, pathogenic processes and various pharmacological. Includes molecules found in blood and fluids.
- Commonly used biomarkers are tumour markers, tumour markers, inflammatory markers and imaging markers.

Sources of biomarkers includes biological fluids, tissues, imaging/physiology.

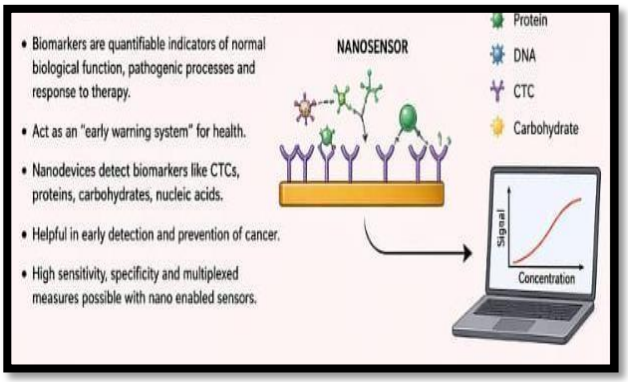

Fig.04- Biomarkers

- Biomarkers are sometimes used to see how the body responds to a treatment for a disease or condition.

Applications:

- To confirm the presence of disease.
- To show how a drug reached its target and produce intended pharmacological effect.
- To detect toxicological effects or off target drug actions.
- In assessment of severity of disease.
- Used to identify individuals' risk of developing diseases.[8]

IV. Mechanism of Nanotechnology

Drug Loading
↓
Nanoparticle Formation
↓
Administration (Injection / Oral)
↓
Blood Circulation
↓
Tumour Targeting
(Passive – EPR effect)
(Active – Ligands/Antibodies)
↓
Cellular Uptake
(Endocytosis by cancer cells)
↓
Stimuli-Responsive Drug Release
(pH / Enzymes / Temperature)
↓
Drug Action
(Kills cancer cells)
↓
Reduced Side Effects on Normal Cells

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

IV. Nanoparticles in cancer therapy

Nanoparticles refers to the particles ranging from (1 to 100nm) which has evolved cancer treatment by enhancing targeted drug delivery, reducing systemic toxicity by selective targeting and delivery to cancer tissues. Nano carriers increase the half-life of the drugs.

- Nanotechnology is used to immunostimulatory and or immunomodulatory molecules.[9]

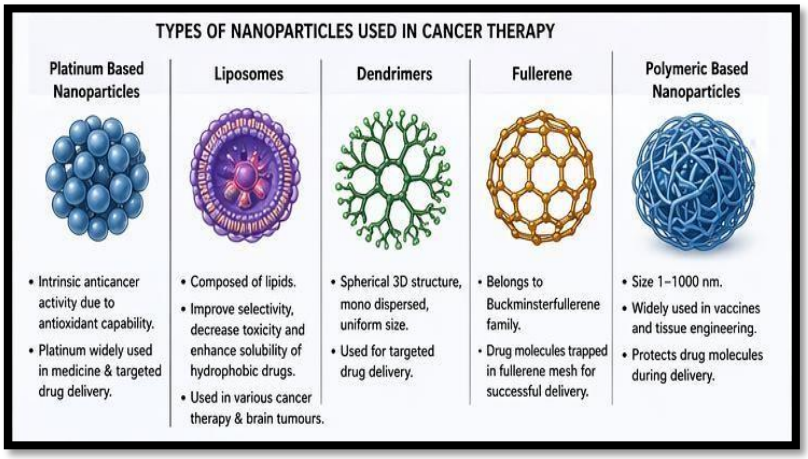

Fig.05- Types of Nano Particles used in Cancer Therapy.

3.4 Platinum Based

- Nanoparticles possess intrinsic anticancer activity because of their antioxidant capabilities which has inhibitory effect on growth of tumours.
- Platinum is widely in medicine & functionalized targeted drug delivery without affected healthy cells. [10]

3.5 Liposomes

- Liposomes are composed lipids. They are novel in pharmaceutical drug delivery systems. Liposomes had a significant impact on chemotherapy as they can improve selectivity, decrease toxicity and enhance solubility of hydrophobic drugs.
- Liposomes are used in various cancer therapy and in treatment of brain tumours. [11]

3.6 Dendrimers

These are the novel architectures with characteristics such as a spherical threedimensional shape, a mono dispersed uni-micellar nature, and a nonmetric size range Dendrimers are used for targeted drug delivery.[12]

3.7 Fullerene

Fullerene belongs to Buckminsterfullerene family, fullerene has been used in chemical applications, where drug molecules can be trapped in fullerene mesh for successful drug delivery.[13]

3.8 Polymeric Based Nanoparticles

- Polymeric nanoparticles with size ranging from 1 to 1000 nm. Polymeric nanoparticles are widely used in vaccines and tissues engineering.
- They have the ability to protect the drug molecules during the delivery of drug.

3.9 Nanotechnology in Radiotherapy

This involves targeted delivery of radioisotopes, radiosensitizer, and reduce side effects of radiotherapy by decreasing its distribution to healthy tissues.

3.10 Controlled Drug Release

Nanoparticles can release drugs in controlled manner in response to stimuli such as pH, temperature or enzymes. [14]

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

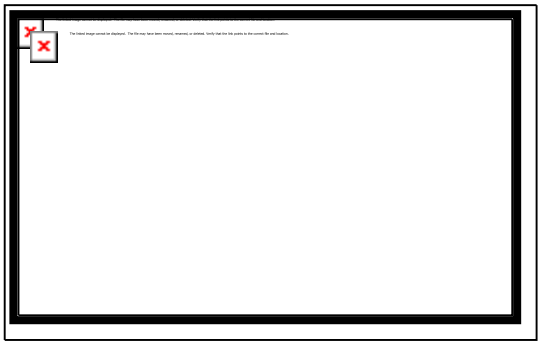

Fig.06- Controlled Drug Release

3.11 Photo thermal Therapy

- In this therapy, the nanoparticles are generally used for converting the light into heat which destroy cancerous cells. It is currently used in precision oncology and target infection control.
- Photo thermal therapy is used for killing bacteria in localized infection.
- Currently Photo thermal therapy techniques are used preclinical and clinical trials by focussing on developing biodegradable, biocompatible, and highly efficient photothermal agents.[15]

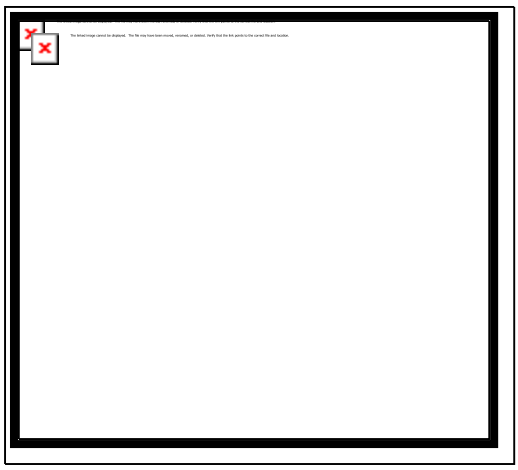

Fig.07- Photo Thermal Therapy.

3.12 Gene therapy

Nanoparticles serve as carriers for delivering genetic material such as DNA or RNA to modify the gene expression in cancer cells.

3.13 Targeted Drug Delivery

- Targeted drug delivery means delivery of drug to the targeted site without affecting the healthy tissues.
- Nano carriers such as liposome, dendrimers and polymeric nanoparticles deliver drug directly to cancer cells.[16]

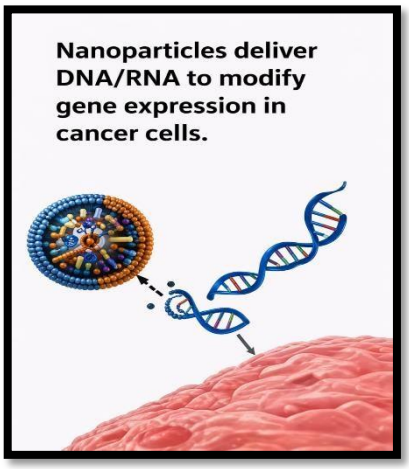

Fig.08- Gene Therapy

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

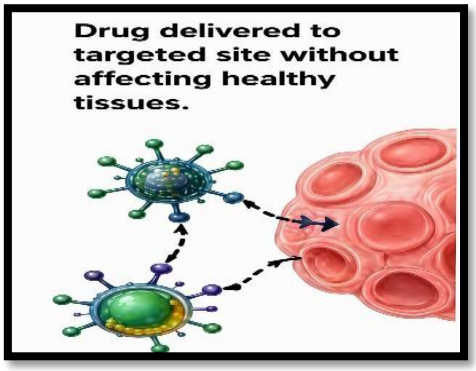

Fig.09- Targeted Drug Delivery System

4. Limitation

- Complex scalability and synthesis issues
- Regulatory and safety concerns
- High production & development costs
- Possible toxicity biocompatibility concerns - Limited understanding of long-term effects

5. Difference between conventional and Advanced Nanotechnology in Cancer

CONVENTIONAL vs ADVANCED NANOTECHNOLOGY IN CANCER

ASPECT	CONVENTIONAL NANOTECHNOLOGY	ADVANCED NANOTECHNOLOGY
Definition	Early-stage or basic nanoparticle systems used mainly as drug carriers.	Highly engineered, multifunctional nanosystems for targeted delivery, diagnosis and therapy (theranostics).
Targeting	Passive targeting through Enhanced Permeability and Retention (EPR) effect. Limited specificity to cancer cells.	Active targeting using ligands, antibodies, aptamers. Recognizes specific tumor biomarkers for higher precision.
Drug Delivery Efficiency	Improves solubility and circulation time. Drug release is often uncontrolled or slow diffusion-based.	Stimuli-responsive release (pH, temperature, enzymes, light, etc.). Delivers drugs specifically at tumor site; minimizes side effects.
Functionality	Single function – mainly drug delivery.	Multifunctional – drug delivery + imaging (MRI, fluorescence) + therapy (photothermal, photodynamic) + gene delivery, etc.
Types of Systems	Liposomes, polymeric nanoparticles, micelles, solid lipid nanoparticles, etc.	Smart nanoparticles, dendrimers, quantum dots, gold nanoparticles, nanorobots (experimental), etc.
Control & Precision	Limited control over drug release and distribution.	High control using stimuli-responsive systems and integration with biotechnology and AI. Responds dynamically to tumor environment.
Diagnostic Capability	Minimal or no diagnostic role.	Integrated diagnostic and therapeutic capability (theranostics); enables early detection and real-time monitoring.
Side Effects & Safety	Higher systemic toxicity due to non-specific distribution.	Reduced side effects due to targeted delivery and controlled release.
Challenges	Less efficient targeting, higher toxicity, limited functionality.	Complex design, high cost, regulatory hurdles, long-term toxicity under investigation.
Overall Goal	Improve drug delivery and therapeutic outcome to some extent.	Precision oncology – accurate diagnosis, targeted therapy, minimal side effects, personalized cancer treatment.

International Journal of Pharmaceutical research and Applications
Volume 11, Issue 3, May-June2026, pp:1963-1971 www.ijprajournal.com ISSN:2456-4494

6. Recent Advancements

- Development of TDDS
- In Gene therapy, nanocarriers are now being used to deliver genetic material like DNA, RNA or mRNA into cells
- Plays eminent role in nanorobotics
- Contributing to tissue engineering and regenerative medicine.
- Nano imaging agents improved MRI, fluorescence imaging.

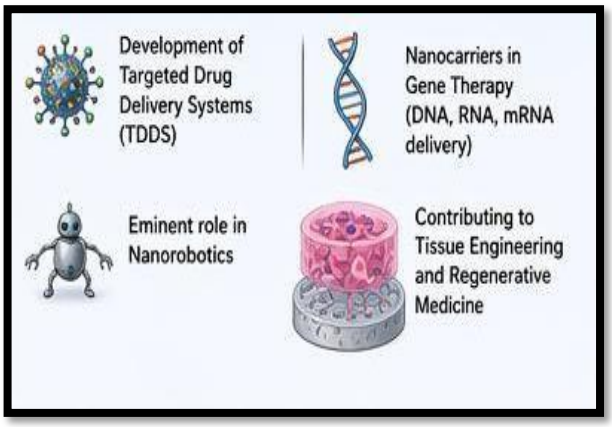

Fig.10 Recent Advancements

Photo thermal /Photodynamic therapy involves cancer cell destruction.

- Nanotheranostics involves diagnosis and therapy in one system.
- Nano based Early detection of cancer (Biosensors) helps in detection of DNA mutation at early stage.
- Magnetic nanoparticles involve heated using magnetic field which can kill cancerous cell. [17]

7. Future perspective

- Future advancements in nanotechnology are expected to focus on developing smart nanoparticles capable of responding to external stimuli.
- Nano robots and multifunction nano devices hold promise for efficient cancer therapy.
- Personalized medicines or Nano carriers based on patient genetic profile.
- Combination of Nano diagnostics tools and AI for monitoring of cancer progression.
- Nanoparticles delivering CRISPR, siRNA, mRNA for gene editing and RNA therapy. Nano immunotherapy for stronger, targeted immune responses. [18]

CONCLUSIONS

Nanotechnology has revolutionized cancer diagnosis and therapy. It helps in early detection, targeted treatment, and reduce side effects. Also, the development of multifunctional nanoparticle that are able to carry imaging agents and deliver multiple drugs enhanced the detection & treatment of cancer. By addressing limitations of conventional modalities such as non-specificity, systemic toxicity and poor therapeutic monitoring nanomaterials and can enhance targeted drug delivery precision, and open new avenues for immunotherapy and gene editing. Nanotechnology has shown a lot of promise in cancer therapy over the years.

By their improved pharmacokinetic and pharmacodynamic properties, nanomaterials have contributed to improved cancer diagnosis & treatment Nanotechnology allows targeted drug delivery in affected organs with minimal systemic toxicities due to their specificities. However, as with other therapeutic options, nanotechnology is not completely devoid of toxicities and comes with few challenges with its use including systemic and certain organ toxicities These are particularly useful as drug delivery system due to their tiny size and unique surface properties. Drugs such as doxorubicin, daunorubicin, mitoxantrone paclitaxel, cytarabine, irinotecan and amphotericin B are already being conjugated with liposomes for their delivery in current clinical practices.

Doxorubicin, cytarabine, vincristine, daunorubicin, mitoxantrone, and paclitaxel in particular, are key components of chemotherapy Even in the diagnosis of cancer for imaging and detection of tumour markers particle such as nano

shells, dendrimers, and gold nanoparticles are currently in use By improving the interaction between the physicochemical properties of the nanomaterials employed safer and more efficacious derivatives for diagnosis and treatment can be made available for cancer management. The therapeutic benefits could make them a therapeutic potential to be applied in other disease conditions. Despite existing many challenges continued research and technological advancements to make nano medicine a cornerstone in modern oncology.

REFERENCES.:

[1]. Alrushaid, N., Khan, F. A., Al-Suhaimi, E. A., &Elaissari, A. (2023).
[2]. Nanotechnology in cancer diagnosis and treatment. *Pharmaceutics*, *15*(3), 1025.
[3]. Dessale, M., Mengistu, G., &Mengist, H. M. (2022). Nanotechnology: a promising approach for cancer diagnosis, therapeutics and theragnosis. *International Journal of Nanomedicine*, 3735-3749.
[4]. Tantray, J., Patel, A., Parveen, H., Prajapati, B., & Prajapati, J. (2025). Nanotechnology-based biomedical devices in the cancer diagnostics and therapy. *Medical Oncology*, *42*(2), 50.
[5]. Mosleh-Shirazi, S., Abbasi, M., rezaMoaddeli, M., Vaez, A., Shafiee, M., Kasaee, S. R., ... & Hatam, S. (2022). Nanotechnology advances in the detection and treatment of cancer: an overview. *Nanotheranostics*, *6*(4), 400.
[6]. Kher, C., & Kumar, S. (2022). The application of nanotechnology and nanomaterials in cancer diagnosis and treatment: a review. *Cureus*, *14*(9).
[7]. Liang, M., Li, L. D., Li, L., & Li, S. (2022). Nanotechnology in diagnosis and therapy of gastrointestinal cancer. *World Journal of Clinical Cases*, *10*(16), 5146.
[8]. Khanduri, N. (2024). An Overview on Nanotechnology and Cancer Diagnosis and Therapy. *RESEARCH REVIEW International Journal of Multidisciplinary*, *9*(3), 140-143.
[9]. Shirzad, M., Shaban, M., Mohammadzadeh, V., Rahdar, A., Fathi-karkan, S., Hoseini, Z. S., ... &Aboudzadeh, M. A. (2025). Artificial intelligence-assisted design of nanomedicines for breast cancer diagnosis and therapy: advances, challenges, and future directions. *BioNanoScience*, *15*(3), 354.
[10]. Chatterjee, P., & Kumar, S. (2022). Current developments in nanotechnology for cancer treatment. *Materials Today: Proceedings*, *48*, 1754-1758.
[11]. Khanduri, N. (2024). An Overview on Nanotechnology and Cancer Diagnosis and Therapy. *RESEARCH REVIEW International Journal of Multidisciplinary*, *9*(3), 140-143.
[12]. Kasaai, M. R. (2026). Nanotechnology-based Strategies in Breast Cancer Diagnosis and Therapy: A Mini-review. *Oncology Advances*, *4*(1).
[13]. Feng, J., Zhang, P., Wang, D., Li, Y., & Tan, J. (2024). New strategies for lung cancer diagnosis and treatment: applications and advances in nanotechnology. *Biomarker Research*, *12*(1), 136.
[14]. Wang, B., Hu, S., Teng, Y., Chen, J., Wang, H., Xu, Y., ... & Gao, X. (2024). Current advance of nanotechnology in diagnosis and treatment for malignant tumors. *Signal Transduction and Targeted Therapy*, *9*(1), 200.
[15]. Umapathy, V. R., Natarajan, P. M., &Swamikannu, B. (2023). Review of the role of nanotechnology in overcoming the challenges faced in oral cancer diagnosis and treatment. *Molecules*, *28*(14), 5395.
[16]. Tiwari, H., Gupta, P., Verma, A., Singh, S., Kumar, R., Gautam, H. K., & Gautam, V. (2024). Advancing era and rising concerns in nanotechnology-based cancer treatment. *ACS Chemical Health & Safety*, *31*(2), 153-161.
[17]. Duleh, M. A., Guduru, R. K. R., & Bangash, S. A. (2025). Synergizing AI, IoT, and nanotechnology for innovative medical diagnostics and therapeutic solutions. *Journal of Neonatal Surgery*, *14*(20s).
[18]. Moreddu, R. (2024). Nanotechnology and cancer bioelectricity: bridging the gap between biology and translational medicine. *Advanced Science*, *11*(1), 2304110.
[19]. Zhang, J., Ding, H., Zhang, F., Xu, Y., Liang, W., & Huang, L. (2023). New trends in diagnosing and treating ovarian cancer using nanotechnology. *Frontiers in Bioengineering and Biotechnology*, *11*, 1160985.