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“Smart Nanotechnology For Cancer Therapy”

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Abstract:

Cancer treatment has progressed from traditional chemotherapy, which targets all rapidly dividing cells and causes significant side effects, to more precise and less toxic approaches. Targeted therapies, such as antibody-drug conjugates, aim to affect only cancer cells, though they can still lead to complications like high blood pressure and heart issues. A major challenge in cancer therapy remains drug resistance and ineffective delivery due to the tumor microenvironment. To address this, researchers have developed smart nanoparticles—engineered to respond to stimuli like pH or temperature—for controlled drug release and targeted delivery. These nanocarriers, including polymer-based, biomimetic, and inorganic types, improve treatment precision and reduce side effects. They can be administered via various routes such as intravenous, oral, intratumoral, and intranasal. Targeting is enhanced by attaching ligands to receptors overexpressed on cancer cells, such as folate receptors. Polymers like PEG and HPMA are often used in drug delivery systems due to their safety and biodegradability. Nanoparticles also enhance radiotherapy by increasing radiation absorption at tumor sites. Overall, the integration of nanotechnology and molecular biology is enabling more personalized, effective, and less harmful cancer treatments.

Key words: Nanoparticles , Types of nanocarrier ,Route of administration,Targeting drug for cancer treatment , Application

INTRODUCTION :

Cancer treatment has evolved significantly over the years. Chemotherapy, a traditional method, works by killing rapidly dividing cells, including cancer cells

Bone marrow suppression: This reduces blood cell production, increasing the risk of infections, anemia, and bleeding.

- **Hair loss (alopecia):** Chemotherapy can cause hair to fall out, though this is usually temporary.
- **Gastrointestinal issues:** Nausea, vomiting, diarrhea, and mouth sores are common.

These side effects can significantly impact a patient's quality of life. To address these challenges, researchers have developed targeted therapies. These treatments aim to specifically target cancer cells, sparing healthy ones. For instance, drugs like antibody-drug conjugates deliver chemotherapy directly to cancer cells, reducing damage to normal tissues. While these therapies are more precise, they can still cause side effects such as high blood pressure, bleeding, and heart issues. Despite advancements, drug resistance remains a significant hurdle. Cancer cells can adapt and become less responsive to treatments over time. Researchers are exploring new strategies, including nanoparticle-based drug delivery systems, to overcome this resistance and improve treatment outcomes. In summary, while chemotherapy has been a cornerstone in cancer treatment, its side effects have prompted the development of more targeted therapies. Ongoing research aims to enhance treatment efficacy and address challenges like drug resistance. [1]

Cancer remains a major global health challenge, leading to approximately 10 million deaths annually. Chemotherapy has been a cornerstone of cancer treatment due to its effectiveness. However, its widespread use is hampered by several limitations, including lack of selectivity for tumor cells, inefficient drug delivery to tumor sites, and the development of multi-drug resistance. Additionally, the complexity of the tumor microenvironment (TME) and individual patient variations further complicate treatment strategies. In response to these challenges, the development of smart nanoparticles (NPs) has emerged as a promising alternative to conventional drug delivery methods. Unlike traditional NPs, smart NPs can be engineered to respond to specific stimuli—such as pH changes, temperature variations, enzymes, or light—enabling targeted and controlled drug release at tumor sites. This responsiveness allows for enhanced drug accumulation at the tumor location, minimizing damage to healthy tissues and improving treatment efficacy. Furthermore, smart NPs can be functionalized with tumor-specific ligands, such as antibodies or peptides, to actively target cancer cells. This targeted approach not only improves the precision of drug delivery but also facilitates the co-delivery of therapeutic agents and diagnostic tools, advancing the field of cancer theranostics. By integrating treatment and diagnostic capabilities into a single platform, smart NPs offer a more personalized and effective approach to cancer therapy. Despite their potential, the clinical application of smart NPs faces challenges, including complex manufacturing processes, potential toxicity,

and the need for extensive clinical validation. Nonetheless, ongoing research and development in nanotechnology continue to drive advancements in smart NP-based cancer therapies, holding promise for more effective and individualized treatment options in the future.

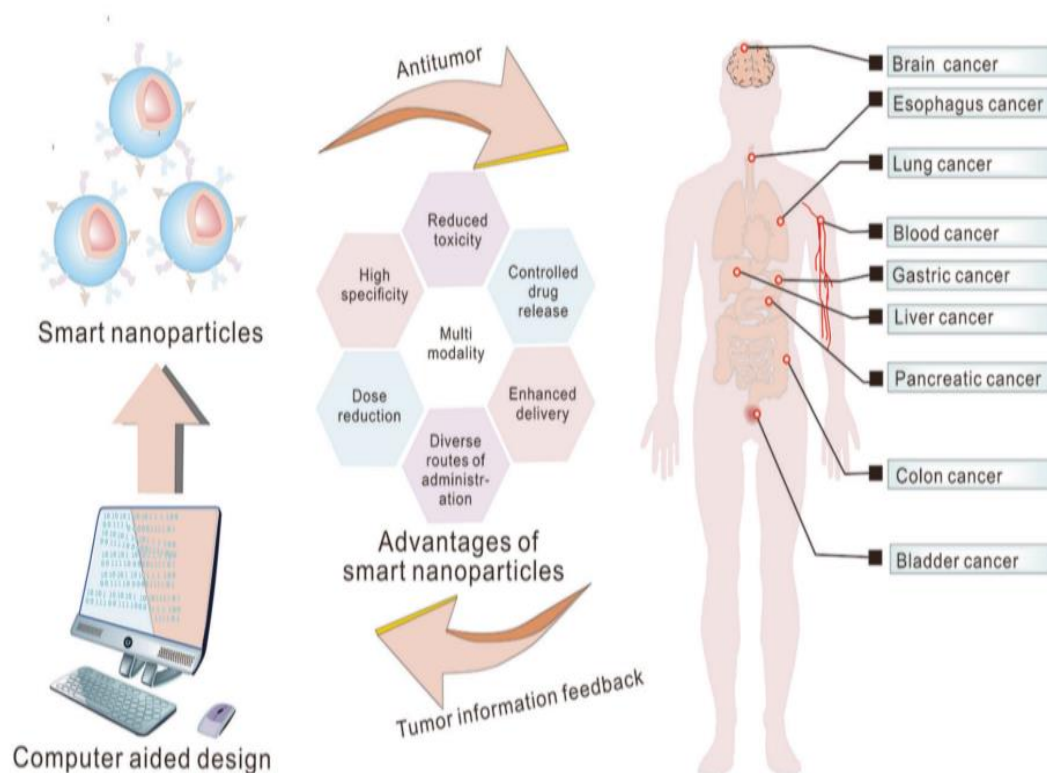


Fig. 1 Schematic illustration of smart nanoparticles for cancer treatment

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Cancer treatment has evolved significantly over the years. Chemotherapy, a traditional method, works by killing rapidly dividing cells, including cancer cells. However, it also affects healthy cells, leading to side effects such as:

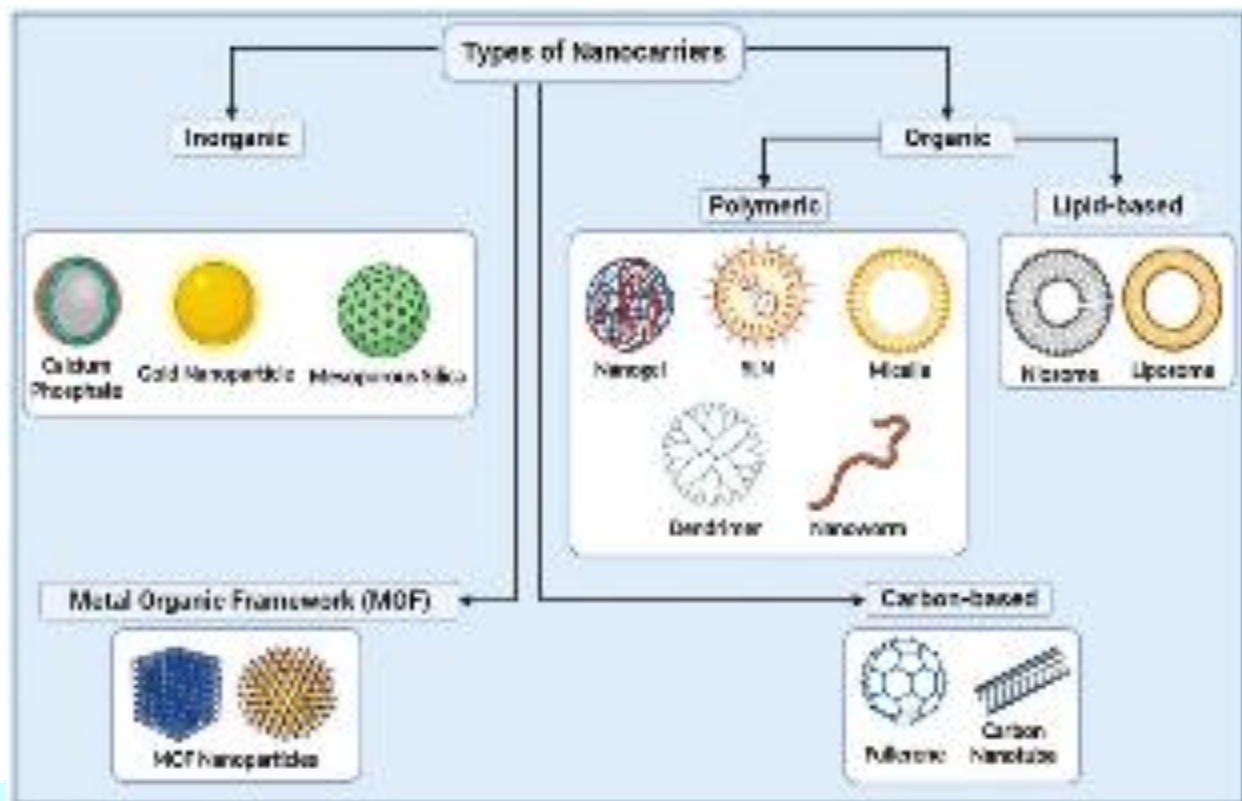
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cancer.

Nanocarriers: Liposomes and micelles carrying chemotherapeutic agents.

6. Topical and Transdermal Delivery

Nanocarriers: Nanoemulsions, liposomes, solid lipid nanoparticles.

7. Intranasal Delivery Target: Brain cancers

Different administration route:

1. Intravenous injection Most common route for nanocarrier-based cancer therapy.

Advantages: Rapid systemic distribution. Allows for passive (EPR effect) and active tumor targeting. Examples: Liposomes (e.g., Doxil), polymeric nanoparticles, micelles.

2. Oral Administration Challenges: Harsh gastrointestinal environment. First-pass metabolism. Examples: Nanostructured lipid carriers for oral paclitaxel.

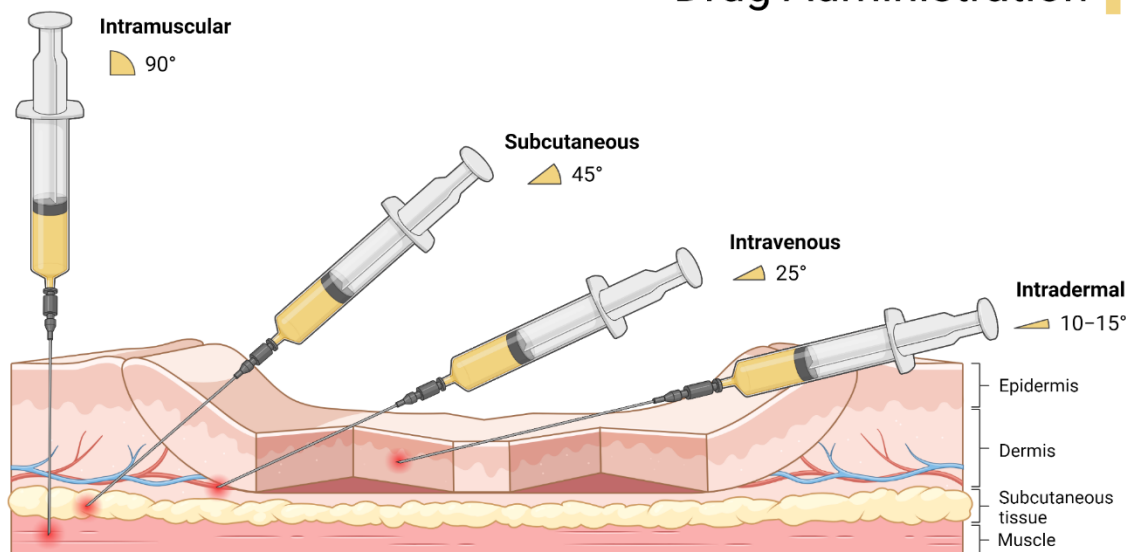
3. Inhalation (Pulmonary) Target: Lung cancers..

Nanocarriers: Aerosolized liposomes, solid lipid nanoparticles, polymeric nanoparticles.

4. Intratumoral Injection Direct injection of nanocarriers into the tumor. Examples: Injectable hydrogels with nanoparticles.

5. Intraperitoneal (IP) Injection Used for: Peritoneal cancers like ovarian

Parenteral Route of Drug Administration



Surface Receptors and Antigens

For use in drug delivery, these materials must be safe, stable, and not release harmful substances. Some examples of polymers being studied or already used include:

Polyvinyl alcohol

Poly(N-vinyl pyrrolidone)

Polyacrylamide

Some well-known polymers used in medicine Receptors and antigens are unique molecules found on the surface of cells. Scientists can use these act like targets to help send chemotherapy drugs straight to cancer cells. For the drug to be delivered effectively, these receptors or antigens need to be found in large amounts on the cancer cells. Also, the drug-carrying molecule (like a ligand or antibody) should stick strongly to these targets. Ideally, after the drug binds to the receptor, the cell should absorb (endocytose) the drug quickly. Then, once the drug is released inside the cell, the receptor or antigen should return to the surface so it can work again. However, many receptors used for targeting cancer are also found on normal (non-cancer) cells. For example, receptors like the epidermal growth factor receptor or the low-density lipoprotein receptor are common in many types of cells. Some receptors are more specific to tumors. For instance, folate receptors are found in large amounts on cancers of the ovary, brain, kidney, breast, and

lungs. Because of this, scientists are developing drug-loaded nanoparticles that specifically attach to folate receptors.

Polymers for Drug Delivery

include:

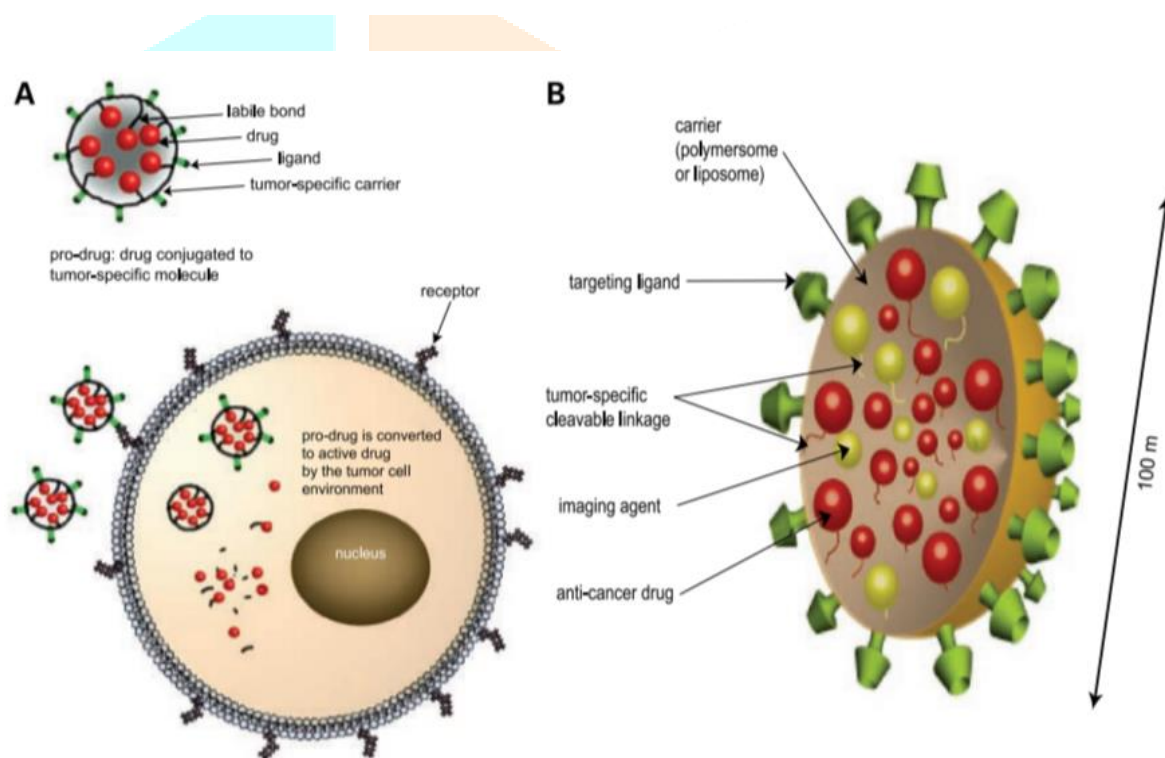
Polyethylene glycol (PEG)

Polystyrene maleic anhydride co-polymer

HPMA (a special methacrylamide polymer)

Polyglutamic acid (PG)

Polymers are usually part of drug delivery systems such as drug conjugates, micelles (tiny carriers), or non-viral vectors (carriers that are not viruses). One very important feature of polymer for drug delivery is biodegradability. This means the polymer can break down into safe, natural substances that the body can easily remove through normal processes.



Targeting Drug For Cancer Treatment :

Scientists have made huge progress in understanding how diseases work at the molecular level and in developing new tools in molecular biology. Because of this, we now have a massive amount of molecular information. In fact, we've discovered many potential drug targets faster than we can actually use them in treatment. Right now, researchers are working hard to create drugs that specifically block the abnormal signals inside cancer cells. This approach could lead to personalized treatments based on the unique features of each person's tumor. Drugs can be given on their own or through special delivery systems that

carry them directly to the tumor or even directly to the cancer cells. For this kind of targeted treatment to work, three things are needed:

1. Specific markers or targets found only in cancer cells,
2. Molecules (called ligands) that can recognize and bind to these targets, and
3. A delivery system that carries the drug to the right place.

Tumors are made up of different types of cells that change over time, which makes delivering medicine to them more difficult. To treat tumors effectively, it's important to understand how tumor cells behave, the environment around them, and how they grow. Medicine can be targeted to tumors by using their unique features or by attaching the drug to special molecules that help it reach the tumor direct

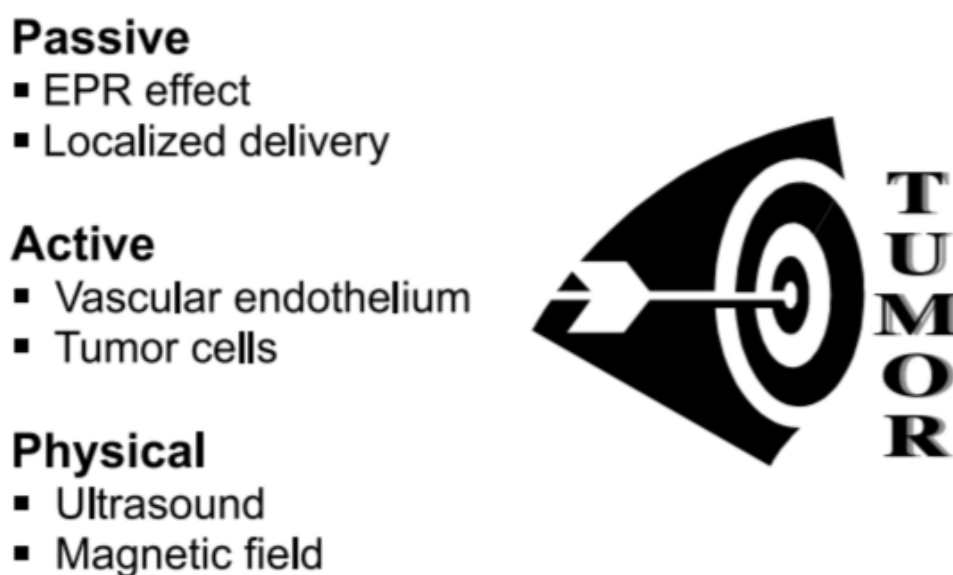


Figure 1: Schematic representing different drug targeting approaches to tumor.

Drug Delivery System :

In nanotechnology, tiny particles called nanoparticles are now being used to deliver drugs in a smarter and more effective way. When used in drug delivery systems (DDS), nanoparticles can: Help drugs last longer in the body, Make poorly soluble drugs (especially oily or water-insoluble ones) easier to absorb, Release drugs slowly or in a controlled way, so they work better over time. Some nanoparticles are even “smart”, meaning they only release the drug in response to specific conditions (like a change in pH or temperature). This can reduce side effects and ensure the drug goes exactly where it's needed in the body. The first kind of nanoparticles used for delivering drugs were liposomes tiny fat-like bubbles that carry drugs. These were developed in the 1960s. Since then, scientists have created many more types of nanoparticles for this purpose.

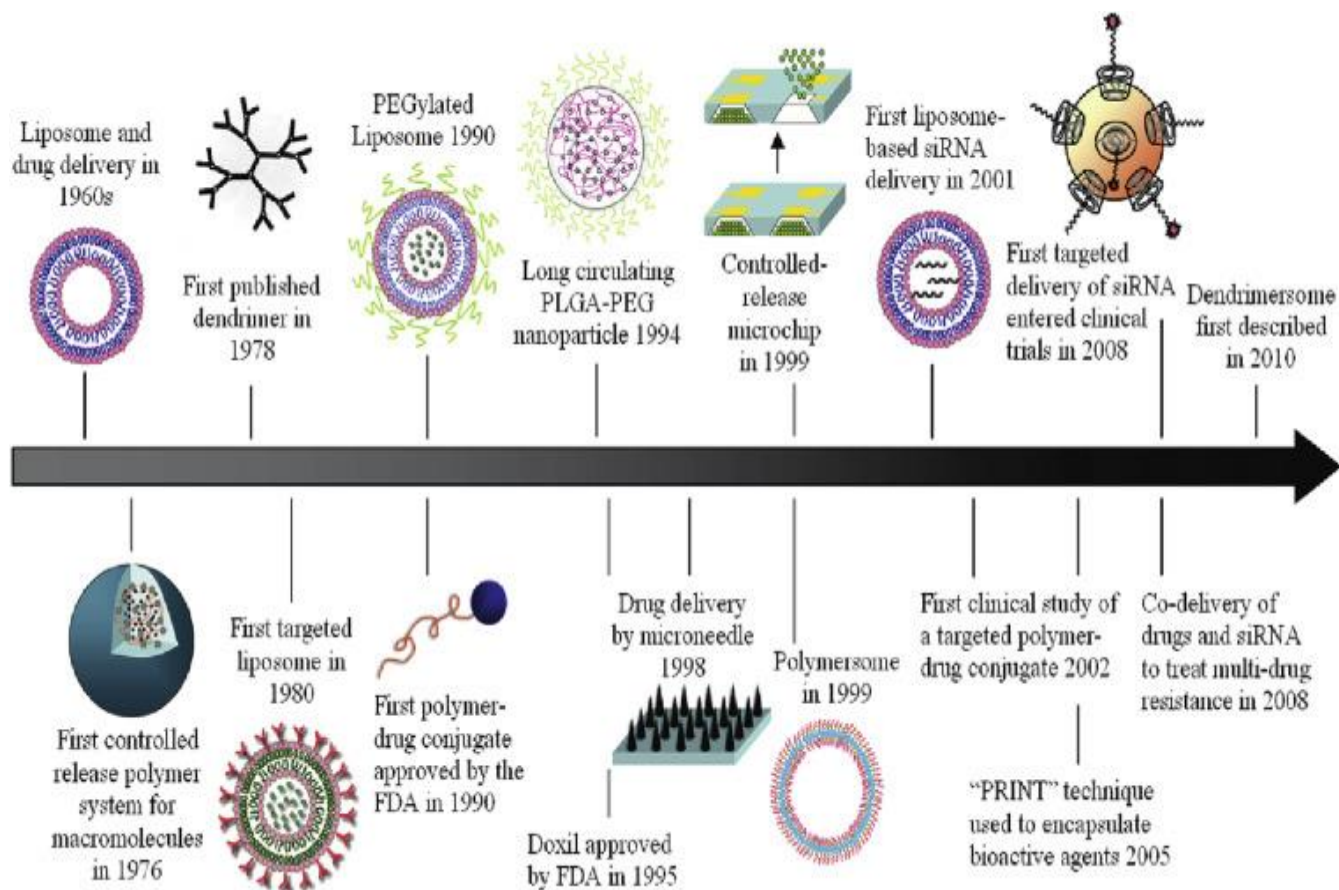


Fig. Timeline for the development of nanoparticle drug delivery systems

1. Targeted Drug Delivery

Mechanism: Nanoparticles can be engineered to carry therapeutic agents directly to tumor cells via passive (e.g., EPR effect) or active targeting (e.g., ligand-receptor interaction). Minimizes exposure to healthy tissues and increases the therapeutic index of drugs. **Mechanism:** Nanocarriers can be designed to release drugs in response to specific stimuli (e.g., pH, temperature, enzymes). **Benefit:** Sustains optimal drug concentration at the tumor site, reducing dosing frequency and side effects

2. Enhancing Radiotherapy

Mechanism: Certain nanoparticles (e.g., gold, hafnium oxide) can increase local radiation dose by enhancing photoelectric effect or generating reactive oxygen species (ROS). **Benefit:** More effective tumor destruction, potentially with lower radiation doses. **Materials:** Gold nanoparticles (AuNPs), hafnium-based nanoparticles (e.g., NBTXR3). **Function:** Increase radiation absorption and cause localized damage to cancer cells.

References:

1. Yihan Yao, Yunxiang Zhou, Lihong Liu, Yanyan Xu, Qiang Chen, Yali Wang, Shijie Wu, Yongchuan Deng, Jianmin Zhang and Anwen Shao Nanoparticle-Based Drug Delivery in Cancer Therapy and Its Role in Overcoming Drug Resistance. *Frontiers in Molecular Biosciences* 20 August 2020 volume 7 article 193 Available from: www.frontiersin.org
2. Bray, F. et al. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: Cancer J. Clin.* 68,394–424 (2018).
3. Leming Sun, Hongmei Liu, Yanqi Ye, Yang Lei, Rehmat Islam, Sumin Tan, Rongsheng Tong, Yang-Bao Miao and Lulu Cai *Signal Transduction and Targeted Therapy* 03 nov.(2023) Available form: www.nature.com/sigtrans
4. Rajni Sinha, Gloria J. Kim, Shuming Nie, and Dong M. Shin Downloaded from mct.aacrjournals.org on May 27, 2020. © 2006 American Association for Cancer Research
5. Au, J. L., Jang, S. H., Zheng, J., Chen, C. T., Song, S., Hu, L., Wientjes, M. G. Determinants of Drug Delivery and Transport to Solid Tumors. *J Control Release* 74, 31-46 (2001).
6. Jaspreet K. Vasir, M.S. Vinod Labhasetwar, Ph.D. Department of Pharmaceutical Sciences College of Pharmacy 986025 Nebraska Medical Center Omaha, NE 68198-6025, USA Department of Biochemistry and Molecular Biology Nebraska Medical Center Omaha, NE 68198-6025, USA volume 4, aug. 2005
7. Maeda, H., Wu, J., Sawa, T., Matsumura, Y., & Hori, K. (2000). Tumor vascular permeability and the EPR effect in macromolecular therapeutics: A review. *Journal of Controlled Release*, **65**(1-2), 271–284.
8. Allen, T. M., & Cullis, P. R. (2004). Drug delivery systems: Entering the mainstream. *Science*, **303**(5665), 1818–1822.
9. Torchilin, V. P. (2005). Recent advances with liposomes as pharmaceutical carriers. *Nature Reviews Drug Discovery*, **4**, 145–160.
10. Her, S., Jaffray, D. A., & Allen, C. (2017). Gold nanoparticles for applications in cancer radiotherapy: Mechanisms and recent advancements. *Advanced Drug Delivery Reviews*, **109**, 84–101.
11. Le Duc, G., Miladi, I., Alric, C., Mowat, P., Bräuer-Krisch, E., Réfrégiers, M., ... & Lux, F. (2011). Toward an image-guided microbeam radiation therapy using gadolinium-based nanoparticles. *ACS Nano*, **5**(12), 9566–9574.
12. Bonvalot, S., Rutkowski, P. L., Thariat, J., Carrère, S., Ducassou, A., Sunyach, M. P., ... & Sarran, A. (2019). NBTXR3, a first-in-class radioenhancer hafnium oxide nanoparticle, plus radiotherapy versus radiotherapy alone in locally advanced soft tissue sarcoma (Act.In.Sarc): A multicentre, phase 2–3, randomised, controlled trial. *The Lancet Oncology*, **20**(8), 1148–1159.

13. Bertrand, N., Wu, J., Xu, X., Kamaly, N., & Farokhzad, O. C. (2014). Cancer nanotechnology: The impact of passive and active targeting in the era of modern cancer biology. *Advanced Drug Delivery Reviews*, **66**, 2–25.
14. Jain, R. K., Stylianopoulos, T. (2010). Delivering nanomedicine to solid tumors. *Nature Reviews Clinical Oncology*, **7**, 653–664

