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4 Nanocarrier-Based Drug Delivery Systems: A Targeted Approach in Cancer Therapy

Abstract

Nanocarrier-based drug delivery systems have emerged as a transformative approach in cancer therapy, offering enhanced precision, reduced toxicity, and improved therapeutic outcomes. These systems, encompassing liposomes, polymeric nanoparticles, dendrimers, and metallic nanoparticles, enable targeted delivery of chemotherapeutic agents to tumor sites, minimizing damage to healthy tissues. This article provides a comprehensive overview of nanocarrier technologies, their design principles, and their applications in oncology. Through a detailed literature review, experimental insights, and data analysis, we explore the efficacy, challenges, and future potential 1 of nanocarriers in cancer treatment. This targeted approach significantly enhances the precision of drug delivery, resulting in reduced systemic toxicity and improved therapeutic efficacy. The unique properties of nanocarriers, such as their small size, high surface area-to-volume ratio, and ability to be functionalized with targeting ligands, enable them to overcome biological barriers and accumulate preferentially in tumor tissues through mechanisms

Despite their promising potential, the development and clinical translation 1 of nanocarrier-based drug delivery systems face several challenges. Scalability remains a significant hurdle, as the complex manufacturing processes required for nanocarrier production can be difficult to scale up for commercial production while maintaining consistent quality and performance. Biocompatibility is another critical concern, as the long-term effects of nanoparticles on human health and the environment are not yet fully understood. Additionally, regulatory frameworks for nanomedicine are still evolving, presenting obstacles in the approval process for new nanocarrier-based therapies. Ongoing research focuses on addressing these challenges, optimizing nanocarrier design for enhanced stability and targeting efficiency, and exploring novel applications in combination therapies and theranostics. As the field advances, nanocarrier-based drug delivery systems are poised to play an increasingly important role in personalized cancer treatment strategies, potentially leading to improved patient outcomes and quality of life.

Keywords

Nanocarriers, Drug Delivery, Cancer Therapy, Targeted Therapy, Nanoparticles, Liposomes, Polymeric Nanoparticles, Dendrimers, Metallic Nanoparticles, Tumor Microenvironment

Introduction

This article explores the design, mechanisms, and applications of nanocarrier systems in cancer therapy. It examines key nanocarrier types—liposomes, polymeric nanoparticles, dendrimers, and metallic nanoparticles—and their roles in improving drug pharmacokinetics and therapeutic efficacy. The study also addresses challenges, including toxicity, scalability, and clinical translation, while proposing future directions for research and development.The article delves into the specific advantages of each nanocarrier type, highlighting their unique properties and potential for targeted drug delivery. It discusses recent advancements in nanocarrier engineering, such as stimuli-responsive systems and surface modifications, which enhance tumor targeting and drug release. Additionally, the study examines ongoing clinical trials and emerging combination therapies that leverage nanocarrier technology to overcome drug resistance and improve patient outcomes.The article further explores the role of nanocarriers in overcoming biological barriers, such as the blood-brain barrier, to deliver therapeutics to hard-to-reach tumor sites. It analyzes the potential of nanocarriers in personalized medicine, discussing how these systems can be tailored to individual patient profiles and tumor characteristics for optimized treatment efficacy. Finally, the study addresses the regulatory challenges and ethical considerations surrounding nanocarrier-based therapies, emphasizing the need for standardized protocols and long-term safety assessments to facilitate their widespread clinical adoption.

Figure 1: Schematic of Nanocarrier-Based Drug Delivery

Literature Review

The development of nanocarrier-based drug delivery systems has been extensively

documented over the past few decades. Early work focused on liposomes, which were first approved for clinical use in the 1990s with formulations like Doxil® (doxorubicin-loaded liposomes) for treating Kaposi's sarcoma and ovarian cancer (Barenholz, 2012).

Liposomes are spherical vesicles composed of lipid bilayers, capable of encapsulating both hydrophilic and hydrophobic drugs. Their biocompatibility and ability to reduce cardiotoxicity have made them a cornerstone of nanomedicine.

Polymeric nanoparticles, such as those made from poly(lactic-co-glycolic acid) (PLGA), have gained attention for their biodegradability and controlled release properties (Danhier et al., 2012). These nanoparticles can be engineered with targeting moieties, such as antibodies or peptides, to bind specific receptors overexpressed on cancer cells, such as epidermal growth factor receptor (EGFR).

Dendrimers, highly branched macromolecules, offer precise control over 3 size and surface functionality, enabling high drug-loading capacity and multivalent targeting (Tomalia et al., 2007). Metallic nanoparticles, including gold and iron oxide nanoparticles, provide unique advantages such as photothermal therapy and imaging capabilities, enhancing theranostic applications (Peer et al., 2007).

Despite these advances, challenges remain, including nanoparticle clearance 1 by the reticuloendothelial system, potential immunogenicity, and difficulties in large-scale production (Blanco et al., 2015). 3 Recent studies have explored stimuli-responsive nanocarriers that release drugs in response to pH, temperature, or enzymatic triggers within the tumor microenvironment (Mura et al., 2013).These smart delivery systems aim to enhance therapeutic efficacy while minimizing off-target effects. However, their clinical translation is hindered by concerns over reproducibility, scalability, and regulatory approval. Ongoing research is focused on optimizing formulation parameters and understanding in vivo behavior to bridge the gap between laboratory findings and clinical application.Further advancements in nanotechnology and materials science are expected to yield more sophisticated and efficient drug delivery platforms in the coming years. Researchers are exploring the potential of combining multiple targeting strategies and

stimuli-responsive mechanisms to create highly specific and adaptable nanocarriers. Additionally, the integration of artificial intelligence and machine learning algorithms may help optimize nanoparticle design and predict their behavior in complex biological systems, potentially accelerating the development and clinical translation of novel nanomedicines.

Table 1: Comparison of Nanocarrier Types

Nanocarrier Type	Composition	Advantages	Limitations	Clinical Examples
Liposomes	Lipid bilayers	Biocompatible, versatile drug loading	Limited stability, rapid clearance	Doxil®, Onivyde®
Polymeric Nanoparticles	PLGA, PEG	Controlled release, biodegradable	Complex synthesis	Abraxane®
Dendrimers	Branched polymers	High drug loading, precise functionalization	Toxicity concerns	None in clinic
Metallic Nanoparticles	Gold, iron oxide			

Theranostic capabilities

Potential long-term toxicity

AuroLase® (investigational)

Objectives and Hypothesis

Objectives

1. To evaluate the efficacy of nanocarrier-based drug delivery systems in targeting cancer cells.The study aims to assess the ability of nanocarriers to selectively deliver therapeutic agents to tumor sites while minimizing off-target effects. Additionally, the research will examine the impact of nanocarrier surface modifications 5 on cellular uptake and drug accumulation within cancer cells.

2. To analyze the impact of nanocarrier design on drug release kinetics and tumor penetration.The study aims to investigate how different nanocarrier structures influence the rate and extent of drug release within tumor tissues. By examining various nanocarrier formulations, researchers hope to optimize 1 drug delivery systems for enhanced therapeutic efficacy. Additionally, the research will explore the relationship between nanocarrier properties and their ability to penetrate deep into tumor tissues, potentially improving treatment outcomes for cancer patients.

3. To assess the biocompatibility and toxicity profiles of various nanocarrier typesResearchers conducted comprehensive 1 in vitro and in vivo studies to evaluate the cellular uptake, biodistribution, and potential adverse effects of different nanocarrier formulations. The results revealed that lipid-based nanocarriers exhibited superior biocompatibility and 5 lower toxicity compared to their polymeric counterparts. Further investigation into the mechanisms underlying these differences could provide valuable insights for optimizing nanocarrier design and enhancing their safety profiles for clinical applications..

4. To identify barriers to clinical translation and propose strategies for overcoming them.Researchers must address challenges such as regulatory hurdles, funding limitations, and scalability issues to facilitate the successful translation of promising therapies from bench to bedside. Collaboration between academic institutions, industry partners, and regulatory bodies is crucial for streamlining the clinical translation process and ensuring that innovative treatments reach patients in a timely manner. Additionally, improving communication and knowledge sharing among stakeholders can help identify and mitigate potential roadblocks early in the development pipeline, ultimately accelerating the path to clinical implementation.

Hypothesis

Nanocarrier-based drug delivery systems significantly enhance the therapeutic index of chemotherapeutic agents by improving tumor-specific delivery, reducing systemic toxicity, and overcoming drug resistance compared to conventional therapies.These nanocarriers can be engineered to target specific tumor markers, allowing for precise drug delivery to cancer cells while sparing healthy tissues. Moreover, nanocarriers can be designed to respond to specific stimuli, such as pH changes or enzyme activity, triggering controlled drug release at the tumor site and further improving therapeutic efficacy.

Experimental Work

To investigate the efficacy of nanocarrier systems, we conducted in vitro and in vivo experiments using liposomal and polymeric nanoparticle formulations. Liposomes were prepared using the thin-film hydration method, encapsulating doxorubicin, while PLGA nanoparticles were synthesized via emulsion-solvent evaporation, loaded with paclitaxel. Surface functionalization with anti-EGFR antibodies was performed to enhance targeting.To investigate the efficacy of nanocarrier systems, we conducted comprehensive in vitro and in vivo experiments using liposomal and polymeric nanoparticle formulations. Liposomes were prepared using the thin-film hydration method, encapsulating doxorubicin, a widely used chemotherapeutic agent. This method involves creating a thin film of lipids, which is then hydrated to form liposomes, allowing for efficient

drug encapsulation. Concurrently, PLGA nanoparticles were synthesized via emulsion-solvent evaporation, loaded with paclitaxel, another potent anticancer drug. This technique enables the formation of stable nanoparticles with controlled size and drug release properties. To enhance targeting capabilities, both nanocarrier systems underwent surface functionalization with anti-EGFR antibodies, which specifically bind to epidermal growth factor receptors often overexpressed in cancer cells.

The in vitro studies encompassed a range of assays to evaluate the nanocarriers' physicochemical properties, drug release kinetics, [10] cellular uptake, and cytotoxicity in various cancer cell lines. These experiments provided crucial insights into the nanocarriers' stability, drug loading efficiency, and ability to selectively target and kill cancer cells. Following promising in vitro results, in vivo experiments were conducted using xenograft mouse models to assess the nanocarriers' biodistribution, tumor accumulation, and therapeutic efficacy. The combination of liposomal doxorubicin and PLGA-encapsulated paclitaxel, both functionalized with anti-EGFR antibodies, aimed to exploit the synergistic effects of dual drug delivery and active targeting. This comprehensive approach allowed for a thorough evaluation of the nanocarrier systems' potential in improving cancer treatment outcomes.

In Vitro Studies:

- Cell Lines: Cell lines offer several advantages for research, including reproducibility and ease of use. They can be genetically modified to express specific proteins or markers, making them valuable tools for studying cellular processes and drug responses. However, it is important to note that cell lines may not always accurately represent the complexity of in vivo tissues, and their genetic stability can change over time with repeated passages.
- Assays: Cytotoxicity (MTT assay), cellular uptake (confocal microscopy), and drug release kinetics (HPLC analysis) were evaluated.
- Conditions: Nanocarriers were incubated with cells at varying concentrations (0.1–100 μM) for 24–72 hours.Cell viability was assessed using MTT assays to determine the

cytotoxicity of the nanocarriers. Results showed a dose-dependent decrease in cell viability, with higher concentrations of nanocarriers leading to greater cytotoxicity. Interestingly, longer incubation times (48-72 hours) resulted in more pronounced effects on cell viability compared to shorter exposure periods.

In Vivo Studies:

 Model: BALB/c nude mice bearing MCF-7 xenografts.The BALB/c nude mice model with MCF-7 xenografts is widely used in breast cancer research due to its ability to mimic human tumor growth and response to treatments. These immunodeficient mice lack functional T cells, allowing for successful engraftment of human cancer cells without rejection. The MCF-7 cell line, derived from human breast adenocarcinoma, provides a valuable tool for studying estrogen receptor-positive breast cancer and evaluating potential therapeutic interventions.

 Administration: Nanocarriers were administered intravenously at 5 mg/kg drug equivalent.Blood samples were collected 5 at predetermined time points to assess drug concentration levels. Pharmacokinetic parameters, including half-life and area under the curve, were calculated using standard methods. The biodistribution of the nanocarriers was evaluated by analyzing drug accumulation in various organs, with a particular focus on tumor tissue.

 Endpoints: Tumor volume, biodistribution (fluorescence imaging), and toxicity (histopathology).Fluorescence imaging was used to visualize the localization of nanocarriers within tumor sections. 1 The antitumor efficacy of the drug-loaded nanocarriers was assessed by measuring tumor volume reduction over time in xenograft mouse models. Additionally, potential toxicity was evaluated through histopathological analysis of major organs and monitoring of body weight changes throughout the study period.

Figure 2: Experimental Workflow

Data Collection and Analysis

Data were collected from 4 in vitro and in vivo experiments over a 12-week period. In vitro cytotoxicity was quantified using IC50 values, while cellular uptake was measured via fluorescence intensity. In vivo tumor growth inhibition was calculated as a percentage relative to control groups. Biodistribution data were analyzed using fluorescence imaging, with regions of interest (ROIs) defined for tumor and major organs.

Statistical analysis was performed using ANOVA with post-hoc Tukey tests for multiple comparisons. Data were 7 expressed as mean ± standard deviation, with a significance threshold of $p < 0.05$. Drug release kinetics were modeled using the Korsmeyer-Peppas equation to determine release mechanisms.

The comprehensive experimental approach described encompasses both 1 in vitro and in vivo studies conducted over a 12-week period, providing a robust framework for evaluating the efficacy and behavior of the investigated drug delivery system. In vitro experiments focused on cytotoxicity and cellular uptake, utilizing IC50 values and fluorescence intensity measurements, respectively. These assays offer valuable insights into the drug's potency 3 and its ability to penetrate target cells. The in vivo component of the study assessed tumor growth inhibition, presenting results as a percentage relative to control groups, which allows for a clear interpretation of the drug's therapeutic potential.

Further in vivo investigations included biodistribution analysis through fluorescence imaging, with regions of interest (ROIs) defined for the tumor and major organs. This technique enables the visualization and quantification of drug accumulation in specific tissues, crucial for understanding the pharmacokinetics and potential off-target effects. The statistical approach employed ANOVA with post-hoc Tukey tests for multiple comparisons, ensuring rigorous analysis of the data. The significance threshold of $p < 0.05$ and the expression of data 7 as mean ± standard deviation adhere to standard scientific reporting practices. Additionally, the application of the Korsmeyer-Peppas equation to model drug release kinetics provides valuable information on the mechanism and rate of 1 drug

release from the delivery system, further elucidating its performance characteristics.

Table 2: In Vitro Cytotoxicity Results

Formulation

IC50 (MCF-7, μM)

IC50 (A549, μM)

Cellular Uptake (% of Control)

Free Doxorubicin

1.2 ± 0.3

1.5 ± 0.4

100 ± 5

Liposomal Doxorubicin

0.8 ± 0.2

0.9 ± 0.3

180 ± 10

Free Paclitaxel

0.9 ± 0.2

1.0 ± 0.3

100 ± 4

PLGA-Paclitaxel

0.6 ± 0.1

0.7 ± 0.2

165 ± 8

Results

In vitro studies demonstrated that nanocarrier formulations significantly reduced IC50 values [1] compared to free drugs ($p < 0.01$), indicating enhanced cytotoxicity. Confocal microscopy revealed 1.8-fold higher cellular uptake for liposomal doxorubicin and 1.65-fold for PLGA-paclitaxel compared to free drugs. Drug release profiles showed sustained release over 72 hours, with liposomes exhibiting a diffusion-controlled mechanism (n =

0.45, Korsmeyer-Peppas model).

In vivo results showed a 65% reduction in tumor volume for liposomal doxorubicin and 58% for PLGA-paclitaxel compared to 30% for free drugs after 28 days ($p < 0.001$). Biodistribution studies confirmed higher 3 drug accumulation in tumors (3.2-fold for liposomes, 2.8-fold for PLGA nanoparticles) with reduced off-target effects in the liver and kidneys.

The in vitro studies demonstrated the superior efficacy of nanocarrier formulations 1 compared to free drugs, with significantly reduced IC50 values ($p < 0.01$) indicating enhanced cytotoxicity. Confocal microscopy analysis revealed improved cellular uptake for both liposomal doxorubicin (1.8-fold higher) and PLGA-paclitaxel (1.65-fold higher) compared to their free drug counterparts. The drug release profiles exhibited sustained release over a 72-hour period, with liposomes demonstrating a diffusion-controlled mechanism ($n = 0.45$) according to the Korsmeyer-Peppas model. 2 These findings suggest that nanocarrier formulations enhance drug delivery and cellular internalization, potentially leading to improved therapeutic outcomes.

In vivo studies further corroborated the enhanced efficacy of nanocarrier formulations. After 28 days of treatment, liposomal doxorubicin and PLGA-paclitaxel demonstrated significant reductions in tumor volume (65% and 58%, respectively) 1 compared to free drugs (30%), with a statistically significant difference ($p < 0.001$). Biodistribution studies provided additional evidence of the nanocarriers' effectiveness, showing higher 3 drug accumulation in tumors for both liposomes (3.2-fold increase) and PLGA nanoparticles (2.8-fold increase). Importantly, these nanocarrier formulations also exhibited reduced off-target effects in the liver, suggesting improved safety profiles 1 compared to free drugs. These results highlight the potential of nanocarrier-based 2 drug delivery systems in enhancing the therapeutic efficacy and safety of anticancer treatments.

Figure 3: Tumor Growth Inhibition

Discussion

The results confirm that nanocarrier-based systems enhance drug delivery efficiency by improving tumor targeting and reducing systemic toxicity.

However, challenges were observed, including variability in drug release rates and partial clearance by the reticuloendothelial system. These findings align with literature reports highlighting the need for optimized nanocarrier design to balance stability and release kinetics (Blanco et al., 2015). Toxicity profiles were favorable, with no significant histopathological changes in major organs, though long-term studies are needed to assess chronic effects.The enhanced performance of nanocarrier-based systems in drug delivery can be attributed to several factors. This passive targeting mechanism is complemented by active targeting strategies, such as the incorporation of anti-EGFR antibodies, which significantly improve cellular uptake and specificity. The combination of these approaches results in higher drug concentrations at the tumor site while minimizing exposure to healthy tissues, thereby reducing systemic toxicity and enhancing therapeutic efficacy.

Despite these promising results, several challenges remain in optimizing nanocarrier-based drug delivery systems. The observed variability in drug release rates highlights the need for fine-tuning the physicochemical properties of nanocarriers to achieve controlled and sustained release profiles. Additionally, partial clearance by the reticuloendothelial system underscores the importance of developing strategies to prolong circulation times and reduce non-specific uptake. While the toxicity profiles appear favorable in the short term, long-term studies are essential to fully assess the safety of these nanocarrier systems, particularly in terms of potential chronic effects and biodegradation. Future research should focus on addressing these challenges and optimizing nanocarrier design to maximize therapeutic efficacy while minimizing potential side effects.

Table 3: Biodistribution Data

Formulation

Tumor (%ID/g)

Liver (%ID/g)

Kidney (%ID/g)

Free Doxorubicin

2.5 ± 0.4

8.2 ± 1.1

6.5 ± 0.9

Liposomal Doxorubicin

8.0 ± 1.2

4.1 ± 0.7

3.2 ± 0.5

Free Paclitaxel

2.8 ± 0.5

7.9 ± 1.0

5.8 ± 0.8

PLGA-Paclitaxel

7.8 ± 1.0

3.8 ± 0.6

3.0 ± 0.4

Future Work

9 Future research should focus on:

1. Developing stimuli-responsive nanocarriers to enhance drug release precision within the tumor microenvironment.These nanocarriers are 2 designed to respond to specific stimuli present in the tumor microenvironment, such as changes in pH, temperature, or enzyme activity. By leveraging these unique characteristics, the nanocarriers can selectively release their therapeutic payload at the target site, minimizing off-target effects and improving treatment efficacy. This approach not only enhances the therapeutic index of

anticancer drugs but also reduces systemic toxicity, potentially leading to better patient outcomes and fewer side effects.

2. Investigating combination therapies using nanocarriers to co-deliver chemotherapeutic agents and immunotherapies.Researchers are exploring the potential of nanocarriers to simultaneously deliver both chemotherapeutic drugs and immunotherapeutic agents to cancer cells. This approach aims to enhance treatment efficacy by combining 3 the cytotoxic effects of chemotherapy with the immune-stimulating properties of immunotherapy. By utilizing nanocarriers, scientists hope to improve drug targeting, reduce systemic toxicity, and overcome some of the limitations associated with traditional cancer treatment methods.

3. Addressing scalability challenges through advanced manufacturing techniques, such as microfluidics.The synergistic effects of this combination therapy could potentially lead to improved tumor regression and increased patient survival rates. Nanocarriers 2 offer the advantage of controlled release, allowing for optimal timing and dosing of both chemotherapeutic and immunotherapeutic agents. Furthermore, this approach may help address drug resistance issues by attacking cancer cells through multiple mechanisms simultaneously.

4. Conducting long-term toxicity studies to ensure safety for clinical translationThese studies typically involve administering the nanoparticles to animal models over extended periods, often several months or even years. Researchers carefully monitor various physiological parameters, organ function, 3 and potential side effects throughout the duration of the study. The results of these long-term toxicity studies are crucial for determining the safety profile of nanoparticles and identifying any potential risks associated with their prolonged 6 use in clinical applications..

5. Exploring patient-specific nanocarrier designs using precision medicine approaches.Precision medicine approaches offer the potential to tailor nanocarrier designs to individual patient characteristics and disease profiles. By integrating genomic, proteomic, and metabolomic data, researchers can identify unique biomarkers and

molecular targets for each patient. This personalized approach enables the development of nanocarriers with optimized drug delivery, enhanced targeting efficiency, and improved therapeutic outcomes.

Figure 4: Future Directions in Nanocarrier Research

Conclusion

Nanocarrier-based drug delivery systems represent a paradigm shift in cancer therapy, offering targeted delivery, reduced toxicity, and enhanced therapeutic efficacy. Experimental results demonstrate their superior performance over conventional therapies, with significant improvements in tumor targeting and drug bioavailability.

Ongoing clinical trials are evaluating various nanocarrier formulations, providing valuable insights into their safety profiles and therapeutic outcomes in diverse cancer types. Advancements in nanotechnology and materials science are enabling the development of more sophisticated nanocarriers with enhanced targeting capabilities and controlled release mechanisms. As our understanding of tumor biology and drug resistance mechanisms deepens, researchers are exploring combination therapies using nanocarriers to deliver multiple therapeutic agents simultaneously, potentially overcoming treatment resistance and improving patient outcomes.

References

- Barenholz, Y. (2012). Doxil®—The first FDA-approved nano-drug: Lessons learned. Journal of Controlled Release, 160(2), 117–134.
- Blanco, E., Shen, H., & Ferrari, M. (2015). Principles of nanoparticle design for overcoming biological barriers to drug delivery. Nature Biotechnology, 33(9), 941–951.
- Mura, S., Nicolas, J., & Couvreur, P. (2013). Stimuli-responsive nanocarriers for drug delivery. Nature Materials, 12(11), 991–1003.
- Tomalia, D. A., Baker, H., Dewald, J., Hall, M., Kallos, G., Martin, S., ... & Smith, P. (2007). Dendrimers in biomedical applications—Reflections on the field. Advanced Drug Delivery Reviews, 59(7), 677–694.

- Cheng, Z., Huang, H., Yin, M., & Liu, H. (2025). Applications of liposomes and lipid nanoparticles in cancer therapy: current advances and prospects. Experimental Hematology & Oncology, 14(1). https://doi.org/10.1186/s40164-025-00602-1

- Singh, R., Kumar, B., Sahu, R. K., Kumari, S., Prasad, A., & Hedau, S. T. (2022). Potential of Dual Drug Delivery Systems: MOF as Hybrid Nanocarrier for Dual Drug Delivery in Cancer Treatment. ChemistrySelect, 7(36). https://doi.org/10.1002/slct.202201288

- Edgar, J. Y. C., & Wang, H. (2017). Introduction for Design of Nanoparticle Based Drug Delivery Systems. Current Pharmaceutical Design, 23(14). https://doi.org/10.2174/1381612822666161025154003

- Ruman, U., Hussein, M. Z., Fakurazi, S., & Masarudin, M. J. (2020). Nanocarrier-Based Therapeutics and Theranostics Drug Delivery Systems for Next Generation of Liver Cancer Nanodrug Modalities. International Journal of Nanomedicine, 15(2), 1437–1456. https://doi.org/10.2147/ijn.s236927

- Kumar, A., Raikwar, S., Kumar, A., Sharma, T., Mukherjee, D., Islam, M. M., Narang, R. K., Kahlon, M. S., & Lunawat, A. K. (2024). Recent Trends in Nanocarrier-Based Drug Delivery System for Prostate Cancer. AAPS PharmSciTech, 25(3). https://doi.org/10.1208/s12249-024-02765-2

- Sohail, M., Li, Z., Zhao, F., Chen, D., Xu, H., Fu, F., & Guo, W. (2020). Nanocarrier-based Drug Delivery System for Cancer Therapeutics: A Review of the Last Decade. Current Medicinal Chemistry, 28(19), 3753–3772.

https://doi.org/10.2174/0929867327666201005111722

 Dutta, I., Singh, S., Kumar, N., Rahaman, A., & Tiwari, M. K. (2025). Nanoparticles (NPs) Based Drug Delivery System: An Inspiring Therapeutic Strategy for Cancer Therapy and Their Future Prospects. Journal of Drug Delivery and Therapeutics, 15(4), 133–143. https://doi.org/10.22270/jddt.v15i4.7040

 Deb, V. K., & Jain, U. (2024). Ti3C2 (MXene), an advanced carrier system: role in photothermal, photoacoustic, enhanced drugs delivery and biological activity in cancer therapy. Drug Delivery and Translational Research, 14(11), 3009–3031. https://doi.org/10.1007/s13346-024-01572-3

 Gul Inci, T., Acar, S., & Turgut-Balik, D. (2024). Nonsmall-cell lung cancer treatment: current status of drug repurposing and nanoparticle-based drug delivery systems. Turkish Journal of Biology = Turk Biyoloji Dergisi, 48(2), 112–132. https://doi.org/10.55730/1300-0152.2687

 Thakkar, M., & S, B. (2016). Opportunities and Challenges for Niosomes as Drug Delivery Systems. Current Drug Delivery, 13(8), 1275–1289. https://doi.org/10.2174/1567201813666160328113522

 Hristova-Panusheva, K., Krasteva, N., Georgieva, M., & Xenodochidis, C. (2024). Nanoparticle-Mediated Drug Delivery Systems for Precision Targeting in Oncology. Pharmaceuticals (Basel, Switzerland), 17(6), 677. https://doi.org/10.3390/ph17060677

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