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A Review: Targeted Drug Delivery System

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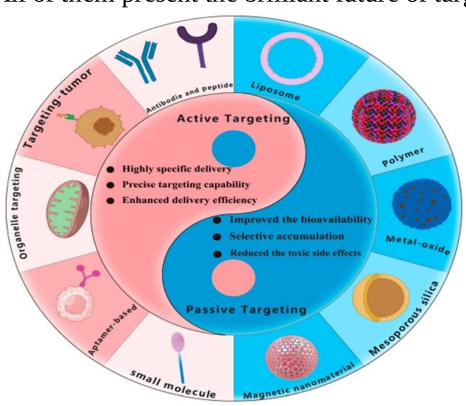
Abstract: This review highlights recent research on targeted drug delivery systems involving NCTD, focusing on passive, active, and physicochemical strategies. These systems aim to improve the drug's bioavailability, enhance therapeutic effectiveness, increase targeting precision, and minimize side effects. The delivery methods covered include direct injection, jet injection, ultrasound, and iontophoresis many of which are adapted from transdermal drug delivery techniques. Direct injection through endoscopy, using needles, has been a standard clinical practice for over a hundred years. Jet injection, a needle-free approach where a high-speed liquid jet delivers drugs into tissues, has been tested in preclinical studies for administration into the buccal mucosa. Other advanced delivery systems involve polymer-drug conjugates and nanoparticles like liposomes, quantum dots, and dendrimers. Additional strategies include attaching therapeutic agents to "targeting ligands," which can specifically bind to tumor-associated antigens. This review, therefore, concentrated on recent studies involving targeted drug delivery systems combined with NCTD, covering passive and active targeting methods, as well as this review highlights recent research on targeted drug delivery systems involving NCTD, focusing on passive, active, and physicochemical strategies.
Keywords: Targeted drug delivery, Drug carriers, Pharmacokinetics.

I. INTRODUCTION

The pharmacological characteristics of a drug determine its biological effects in a patient:

1) The interactions between the drug and the receptors at the drug's site of action are what cause these effects. Unless the drug is delivered to its site of action at a concentration and rate that results in the fewest side effects and the greatest therapeutic effects, the effectiveness of this drug-target interaction has been compromised.
2) Targeted drug delivery is a therapeutic approach in which the therapeutic agent is delivered to a particular tissue while avoiding the rest of the body.
3) As a result, it only administers the drug to the body's targeted regions

The capabilities of targeted drug delivery systems have been greatly expanded by recent developments in materials science and nanotechnology. Innovative drug delivery platforms have surfaced, such as biodegradable polymers, lipid-based systems, and smart materials that react to particular physiological cues .These developments have resulted in better therapeutic outcomes for a range of illnesses, decreased side effects, and increased drug targeting efficiency . Three main factors form the basis of the pharmaceutical justification for targeted drug delivery. First, the therapeutic efficacy of conventional drug formulations may be compromised due to their limited solubility and stability . Second, drugs can be protected from premature degradation and have their bioavailability increased at specific sites by using targeted delivery systems . Third, these systems make it possible to precisely regulate the kinetics of drug release, which enables the development of optimal treatment plans. stages, they hold the key to the future of drug-targeting. The use of nanotechnology in drug delivery has improved the delivery of medication in particular. Similar outcomes have also been achieved with a number of other strategies. All of them present the brilliant future of targeted drug delivery.



Targeted Drug Delivery System (TDDS) is a method of delivering medication directly to a specific site in the body, typically to improve therapeutic efficacy and reduce side effects. Here's a breakdown of its advantages and disadvantages:

A. Advantages of Targeted Drug Delivery Systems

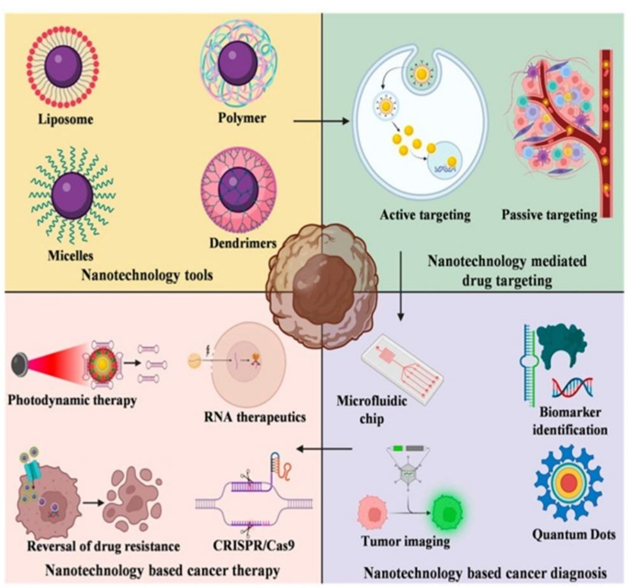
1) Improved Therapeutic Effectiveness: Drug concentration is higher at the target site, enhancing the desired effect.
2) Reduced Side Effects: Less exposure of healthy tissues to the drug minimizes adverse effects.
3) Lower Dosage Required: Because the drug is concentrated where it's needed, smaller doses can be effective.
4) Enhanced Patient Compliance: Fewer side effects and potentially fewer doses can improve adherence to treatment.
5) Controlled and Sustained Release: Many systems allow for gradual drug release, maintaining a therapeutic level over time.
6) Bypasses Biological Barriers: Some systems (like nanoparticles or liposomes) can cross barriers like the blood-brain barrier.
7) Useful for Hard-to-Treat Diseases: Especially effective in cancer, autoimmune diseases, and infectious diseases where targeted action is critical.

B. Disadvantages of Targeted Drug Delivery Systems

1) High Development Cost: Advanced technologies, research, and testing make development expensive.
2) Complex Manufacturing Process: Requires sophisticated equipment and expertise, increasing production complexity.
3) Limited Availability: Not all drugs or diseases are suitable for targeted delivery methods.
4) Potential for Immune Reactions: Some delivery agents (e.g., nanoparticles, liposomes) can trigger immune responses.
5) Stability Issues: Some carriers may degrade before reaching the target, reducing effectiveness.
6) Regulatory Challenges: Gaining approval from regulatory bodies can be more difficult due to complexity and novelty.
7) Targeting Errors: Inaccurate targeting can lead to drug accumulation in unintended sites, causing toxicity.

II. TECHNOLOGIES FOR TARGETED DRUG DELIVERY

1) Nanoparticles: Tiny particles (10-100 nm) made of polymers, lipids, or metals that can be engineered to carry drugs and target specific cells.
2) Liposomes: Spherical vesicles made of phospholipids that can encapsulate drugs and modify their release profiles.
3) Micelles: Nanostructures that self-assemble into spherical shapes, useful for hydrophobic drug delivery.
4) Antibody: Drug Conjugates (ADCs): A combination of an antibody and a cytotoxic drug that allows for specific targeting of cancer cells.
5) Dendrimers: Highly branched, nanoscale polymers that can carry drugs and target specific tissues or cells.
6) Magnetic nanoparticles: Can be guided to specific tissues using an external magnetic field, useful for targeting tumors or infected sites.



III. APPLICATIONS

A. *Cancer Treatment*

Tumor-targeting:

- One of the most significant applications of TDDS is in cancer therapy.
- Targeted drug delivery allows for the delivery of chemotherapy agents directly to the tumor site, reducing damage to surrounding healthy tissues.
- Nanoparticles, liposomes, and antibody-drug conjugates (ADCs) are commonly used in this application.
- These drug delivery systems are designed to recognize and bind to specific receptors overexpressed on cancer cells, such as HER2 (for breast cancer) or EGFR (for lung cancer).
- Example: Herceptin (trastuzumab) is an ADC that targets the HER2 receptor on breast cancer cells.

B. *Gene Therapy*

Nucleic acid delivery:

- TDDS can be used to deliver therapeutic genes or RNA (like mRNA or siRNA) to specific cells or tissues.
- This is essential for correcting genetic disorders at the molecular level.
- Example: Lipid nanoparticles are used in the delivery of mRNA vaccines (like the Pfizer-BioNTech and Moderna COVID-19 vaccines), and similar technology can be adapted for gene therapy for conditions like cystic fibrosis or Duchenne muscular dystrophy.

C. *Infectious Diseases*

Targeted antibiotics or antiviral agents:

- TDDS is used to deliver drugs directly to sites of infection, such as in bacterial or viral diseases.
- This reduces systemic side effects and increases the drug concentration at the infection site.
- Example: Nanocarriers loaded with antibiotics or antiviral agents can target infected tissues, ensuring more efficient drug delivery and overcoming issues like drug resistance.

D. *Neurological Disorders*

Brain-targeted drug delivery:

- The blood-brain barrier (BBB) is a major obstacle in treating neurological conditions. Targeted drug delivery systems can help drugs cross the BBB to treat diseases like Alzheimer's, Parkinson's, and brain tumors.
- Example: Nanoparticles or liposomes can be designed to carry drugs that specifically target brain cells or receptors, improving the treatment of neurodegenerative diseases.

E. *Autoimmune Diseases*

Targeting inflammatory cells:

- TDDS can be used to deliver immunosuppressive drugs directly to areas of inflammation in autoimmune diseases like rheumatoid arthritis, multiple sclerosis, or inflammatory bowel disease.
- Example: Nanocarriers loaded with biologic agents (like monoclonal antibodies) can specifically target immune cells, reducing the overall systemic immune suppression and focusing treatment on affected areas.

F. *Diabetes*

Targeted insulin delivery:

- TDDS can be used for controlled insulin delivery in diabetic patients. Nanoparticles or microparticles can release insulin in response to specific physiological signals, helping to maintain more stable blood glucose levels.
- Example: Insulin-loaded nanoparticles or hydrogels can provide a controlled release, mimicking the natural secretion of insulin from the pancreas.

G. *Ocular Diseases*

Targeted delivery to the eye:

- The eye has unique anatomical challenges, including the blood-retinal barrier and the blood-aqueous barrier, which make it difficult to deliver drugs effectively.
- TDDS can help deliver drugs to specific areas in the eye for conditions like macular degeneration, diabetic retinopathy, and glaucoma.
- Example: Liposomal formulations of drugs or nanoparticles can be used for sustained release in the eye, improving treatment outcomes in ocular diseases.

H. Pain Management

Localized delivery of analgesics:

- In conditions where localized pain relief is needed, like osteoarthritis or post-surgical pain, TDDS can deliver analgesics directly to the site of pain, reducing the risk of systemic side effects such as gastrointestinal irritation or addiction.
- Example: Microneedle patches or nanoparticles that release painkillers such as opioids or NSAIDs directly at the affected site.

I. Vaccines

Targeted vaccine delivery:

- TDDS can improve the efficacy of vaccines by targeting specific immune cells, enhancing the immune response. Lipid nanoparticles are often used for this purpose, as seen with mRNA-based vaccines.
- Example: Lipid nanoparticle-based delivery systems can be designed to optimize the uptake of vaccines by dendritic cells, which are essential for initiating the immune response.

J. Cardiovascular Diseases

Targeted drug delivery for heart disease:

- Drugs aimed at preventing plaque formation in arteries or reducing blood clotting can be delivered specifically to the vascular endothelium (inner lining of blood vessels) to prevent atherosclerosis or thrombosis.
- Example: Targeted liposomes or nanoparticles carrying anti-inflammatory or anti-platelet agents could reduce the risk of heart attacks or strokes by targeting vascular sites prone to plaque buildup.

IV. CAUSES

A. Minimizing Systemic Side Effects

1) Conventional drug delivery often leads to widespread distribution of drugs in the body. This means healthy tissues and organs are exposed to the drug, causing unintended side effects. For instance, chemotherapy drugs used in cancer treatment may kill cancer cells but also harm healthy cells, leading to nausea, hair loss, and immune suppression.
2) Targeted delivery allows for drugs to be delivered precisely to the target area (such as a tumor or infected tissue), minimizing the exposure to healthy tissues and reducing systemic toxicity.

B. Improving Therapeutic Efficacy

1) The goal of targeted drug delivery is to improve the effectiveness of the drug by ensuring that the right dose reaches the right location at the right time. In many cases, conventional therapies result in suboptimal drug concentrations at the site of action, making the therapy less effective.
2) By using targeted delivery, drugs can be concentrated at the site of disease (e.g., cancer cells or infected tissues), increasing their therapeutic action and reducing the required dosage, thereby improving overall treatment outcomes.

C. Overcoming Biological Barriers

1) Biological barriers like the blood-brain barrier (BBB), tissue barriers, and immune system clearance can prevent drugs from reaching their target sites effectively.
2) The blood-brain barrier is particularly challenging in the treatment of neurological diseases (e.g., Alzheimer’s, Parkinson’s, brain cancer), as it restricts the passage of many drugs from the bloodstream into the brain.
3) Targeted drug delivery systems like nanoparticles or liposomes can bypass these barriers and ensure that drugs reach areas that are otherwise difficult to access.

D. Reducing Drug Resistance

1) In diseases like cancer and infections, drug resistance is a significant concern. Tumors or pathogens may become resistant to drugs if the drug is not delivered in sufficient concentrations or is distributed to non-target areas.
2) Targeting the drug directly to the disease cells (e.g., cancer cells or bacteria) ensures that higher concentrations are delivered to the resistant sites, potentially overcoming drug resistance mechanisms like efflux pumps, altered receptor activity, or metabolic inactivation of the drug.

E. Reducing Dosing Frequency and Enhancing Compliance

1) For chronic conditions like diabetes, rheumatoid arthritis, or hypertension, patients often need to take medications regularly. However, frequent dosing can lead to poor patient compliance.
2) Targeted drug delivery can offer a solution by providing controlled and sustained release of drugs, thereby reducing the frequency of administration. For example, microparticles or nanoparticles can slowly release drugs over time, improving patient adherence to treatment regimens.

F. Personalized Medicine

1) Targeted drug delivery plays a key role in the field of personalized medicine. By using specific markers (such as receptors, enzymes, or genetic mutations) found on individual patients' disease cells, TDDS can be customized to target the patient's specific disease profile.
2) This is especially valuable in conditions like cancer, where tumor heterogeneity (differences in the types of cells within a tumor) can influence treatment outcomes. A targeted approach ensures the drug reaches the most relevant part of the tumor, tailoring the therapy to the patient's needs.

G. Reducing Invasive Procedures

1) In some cases, traditional treatments require invasive procedures, such as surgical delivery of drugs or the insertion of catheters to administer drugs directly to a certain site (e.g., in certain brain surgeries or localized tumor treatments).
2) Targeted drug delivery can avoid invasive techniques, enabling the drug to be delivered non-invasively through systems like nanoparticles, liposomes, or microneedles, reducing the risks of infection and complications associated with invasive procedures.

H. Enabling Drug Delivery in Specific Diseases

1) Certain diseases require specialized drug delivery due to the unique environment of the disease site. For example, in cancer, the tumor microenvironment is acidic, hypoxic, and rich in certain enzymes that might require the drug to be specifically activated in that environment.
2) Targeted systems can be engineered to respond to these disease-specific conditions (e.g., using pH-sensitive drug carriers or enzyme-responsive systems) to release the drug only in the desired location.

I. Avoiding Drug Degradation

1) Many drugs are unstable in the bloodstream or are rapidly metabolized, leading to a short half-life or the loss of efficacy. For instance, biologics like proteins or peptides are prone to degradation before they can reach their target.
2) By encapsulating drugs in protective carriers like liposomes, micelles, or nanoparticles, their stability can be enhanced, allowing the drug to reach the target in an active form and reduce degradation before it reaches the site of action.

J. Targeting Chronic Conditions

1) For chronic conditions that require long-term treatment, such as rheumatoid arthritis, diabetes, and multiple sclerosis, targeted delivery helps achieve long-term control over the disease while minimizing the side effects of continuous drug use.
2) A slow-release or site-specific release mechanism allows the drug to be administered at controlled intervals, improving patient quality of life and reducing the frequency of side effects.

V. CONCLUSION

The ability to deliver drugs to specific locations has allowed targeted drug delivery to advance quickly. Because no drug delivery system can effectively deliver drugs to the exact site of action, this results in a lower injection dose and a significant reduction in side effects that were previously more noticeable. Numerous nanoparticles have been approved for clinical use, and while they are still in the development stages, they hold the key to the future of drug-targeting. The use of nanotechnology in drug delivery has improved the delivery of medication in particular. Similar outcomes have also been achieved with a number of other strategies. All of them present the brilliant future of targeted drug delivery .Targeted drug delivery systems are a groundbreaking development in therapeutic medicine that provide previously unheard-of control over drug distribution and release.

REFERANCES

[1] Zhai, B.T.; Sun, J.; Shi, Y.J.; et al. Review targeted drug delivery systems for norcantharidin in cancer therapy. Journal of Nanobiotechnology 2022, 20, 509. DOI: 10.1186/s12951-022-01703-3 Covers liposomes, micelles, nanoparticles, polymer-conjugates etc.
[2] Lu, K.; Cao, M.; Mao, W.; Sun, X.; Tang, J.; Shen, Y.; Sui, M. Targeted acid-labile conjugates of norcantharidin for cancer chemotherapy. J. Mater. Chem. 2012, 22, 15804–15811. DOI: 10.1039/C2JM33069E Uses acid-labile conjugates, polymer–drug conjugates of NCTD with PEI or PLL, with targeting (folic acid) modifications.
[3] Lactoferrin-functionalized PEGylation liposomes loaded with norcantharidin acid for targeted therapy of hepatocellular carcinoma. (2025) Active targeting (ligand: lactoferrin), using liposomes, improved tumor accumulation, improved pharmacokinetics (AUC, half-life).
[4] Metal-organic framework IRMOF-3 coated with a thermosensitive gel delivering norcantharidin to treat liver cancer. Li XY, Guan QX, Shang YZ, et al. World Journal of Gastroenterology 2021; 27(26):4208-4220
[5] Novel polymeric microspheres containing norcantharidin for chemoembolization. PLGA-alginate microspheres loaded with NCTD.
[6] Characterization and Evaluation of a Folic Acid Receptor-Targeted Norcantharidin/Tetrandrine Dual-Drug Loaded Delivery System.
[7] An investigation on liver-targeting microemulsions of norcantharidin.
[8] Targeted Drug Delivery with Polymers and Magnetic Nanoparticles: Covalent and Noncovalent Approaches, Release Control, and Clinical Studies. Chem. Rev. 2016.
[9] Covers polymer & magnetic nanoparticle carriers, passive vs active targeting, ligands, stimuli-responsive release, etc.
[10] Nanoparticles as Drug Delivery Systems: A Review of the Implication of Nanoparticles' Physicochemical Properties on Responses in Biological Systems. MDPI Polymers 2023.
[11] Targeted Drug Delivery of Drugs and Genes Using Polymer Nanocarriers for Cancer Therapy.
[12] Marino M, Jamal Z, Zito P. Pharmacodynamics. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023. Describes how drugs act via interactions with biological targets (e.g. receptors), and how these molecular interactions produce therapeutic and side effects.
[13] "Drug–Receptor Interactions — MSD Manual Professional Edition." This source explains how receptor binding (agonist, antagonist etc.), affinity, efficacy etc., determine the biological effect of a drug.
[14] Defining and unpacking the core concepts of pharmacology: A global initiative. Guilding et al., British Journal of Pharmacology, 2024. Gives definitions for drug targets, drug–target interaction, structure–activity relationships etc
[15] Rana M, Kumar A, Rana AJ. "Drug Delivery through Targeted Approach with Special References to Phytosomes." In Role of Novel Drug Delivery Vehicles in Nanobiomedicine. IntechOpen, 2019/2020. Covers how targeted delivery uses carriers to deliver the drug to a specific site, increasing efficacy and reducing side-effects.
[16] Introductory Chapter: Drug Delivery Concepts. In IntechOpen. This gives the concept of targeted drug delivery ("magic bullet"), delivery to desired tissue to reduce toxicity etc.
[17] Prabahar K., Alanazi Z., Qushawy M. Targeted Drug Delivery System: Advantages, Carriers and Strategies. Indian Journal of Pharmaceutical Education and Research, Vol. 55, Issue 2, April-June 2021.
[18] "Advances in drug delivery systems, challenges and future directions", PMC article. Provides a modern overview including benefits like enhanced performance, precision, controlled/sustained release; also addresses issues like stability, immune response, regulatory and manufacturing complexity.
[19] Targeted Drug Delivery — From Magic Bullet to Nanomedicine, PMC. Talks about reduced toxicity, prolonged circulation, enhanced uptake, etc.
[20] "A Review on Targeted Drug Delivery System", IJRPR. Also lists advantages vs conventional systems: side effects, dose reduction, stability, etc.