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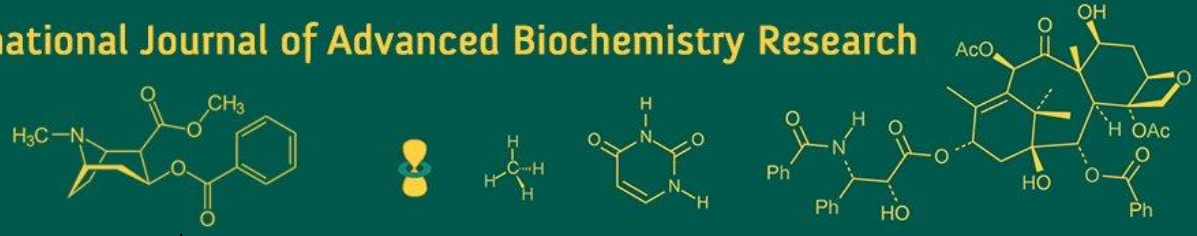

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Innovations in targeted drug delivery: A step towards personalized treatment

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Abstract
A significant number of conventional dosage forms demonstrate suboptimal pharmacokinetic and biopharmaceutical properties, underscoring the need for innovative drug delivery systems capable of selectively targeting the active drug molecule to the intended site of action. Targeted drug delivery (TDD) is a sophisticated approach that ensures precise drug transport to the desired location, reducing systemic side effects and enhancing therapeutic efficacy. By employing various carriers, including nanoparticles, liposomes, niosomes, monoclonal antibodies, and immune cells, TDD achieves sustained and localized drug release. These carriers are tailored based on the drug's properties, delivery route, and disease type, employing mechanisms such as passive, active, and ligand-based targeting. Advanced technologies like nanotubes, nanoshells, and nanobots further enhance the precision of drug delivery. Particularly effective in cancer therapy, TDD minimizes toxicity while improving treatment outcomes. This review highlights the principles of TDD, the production methods of key carriers such as liposomes and nanoparticles, and their diverse biomedical applications, balancing their merits and limitations to showcase the transformative potential of TDD in modern medicine.

Keywords: Liposomes, niosomes, transferosomes, ethosomes, theranostics strategy, precision medicines, nanorobots

Introduction

Introduction to Targeted Drug Delivery

Targeted drug delivery, also known as smart drug delivery, is a specialized approach in pharmacology aimed at selectively delivering medication to specific sites within the body, thereby increasing the drug concentration at the site of interest or target cells while minimizing exposure to non-target tissues (Muller *et al*., 2004) [20]. This strategy enhances therapeutic efficacy, controls drug distribution, reduces side effects, and improves patient compliance, ultimately leading to better treatment outcomes. By focusing on a specific location rather than the entire body or organ, targeted drug delivery aims to achieve higher drug concentrations in the tissue of interest, resulting in increased efficacy at the site of action. Moreover, it reduces toxicity to healthy tissues and enhances the therapeutic index (Ali *et al*., 2015) [2].

Targeted Drug Delivery (TDD) in Cancer Treatment

Cancer can be likened to a weed in a garden where the majority of the flowers are normal, healthy cells. When cancer develops, it behaves like a weed among these flowers. Conventional cancer treatments, such as chemotherapy, act like a weed sprayer applied to the entire garden. While chemotherapy can kill cancer cells, it also affects normal, healthy cells, leading to severe side effects such as nausea, hair loss, and even loss of fertility. Therefore, there is a pressing need for better methods to target cancer cells while sparing healthy ones. Targeted drug delivery addresses this exact problem by selectively targeting cancer cells.

Historical Perspective and Development

A century ago, Paul Ehrlich envisioned the concept of selectively targeting a pathogen without harming the host organism using "magic bullets" (Benyettou *et al*., 2015) [6]. This intriguing idea spurred scientific investigation for over a century, leading to the discovery of

various nanometre-scale devices, now referred to as "nanomedicines" (Barz *et al*., 2015) [5]. These advancements have paved the way for modern targeted drug delivery systems, revolutionizing the way we approach treatment for various diseases, particularly cancer.

Ideal Characteristics of Targeted Drug Delivery Systems

Ideal targeted drug delivery systems should be non-toxic, non-immunogenic, and stable both in the body and in lab conditions. They should direct drugs precisely to target cells or tissues, ensuring even capillary distribution and predictable, steady drug release that doesn't affect drug action. These systems must deliver an effective therapeutic dose with minimal leakage, use biodegradable or easily eliminated carriers that don't impact the disease state, and be simple, reproducible, and cost-effective to produce. (Nagoba *et al*., 2018) [22]

Advantages of Targeted Drug Delivery Systems

Prolonged drug delivery systems offer extended, gradual release, eliminating frequent dosing and boosting patient adherence. They provide stable plasma levels, minimize response variability, and lower required doses, reducing toxicity by targeting specific sites. These systems also enable self-administration and enhance drug absorption efficiency. (Nagoba *et al*., 2018) [22]

Challenges of Targeted Drug Delivery Systems

Targeted drug delivery faces challenges, including complex manufacturing and handling, rapid clearance from the body, and issues with drug diffusion and stability. These systems require advanced technology, are costly, and generally yield lower production outputs. (Nagoba *et al*., 2018) [22]

Applications of Targeted Drug Delivery Systems

- **Disease Treatment:** Targeted drug delivery supports treatment for conditions like cardiovascular disease and diabetes, with regenerative techniques aiding heart repair through stem cell therapies that restore heart function.
- **Tuberculosis Therapy:** Liposome-based delivery improves TB treatment, ensuring better macrophage access and optimal drug concentration.
- **Cancer Research:** 3D-printed tumor models in cancer research allow precise testing of drugs' effects on cancer cells.
- **Protein and Pathogen Detection:** Facilitates identification of specific proteins and pathogens.
- **Tissue Engineering:** Key for building and repairing tissues.
- **MRI Contrast Enhancement:** Enhances imaging contrast in MRI.
- **Gene and Drug Therapy:** Crucial for delivering genetic and drug therapies.
- **DNA Analysis:** Assists in DNA structure exploration.
- **Drug Discovery:** Contributes to developing new therapies. (Nagoba *et al*., 2018) [22]

Principle

Drug delivery (DD) involves specialized methods, formulations, technologies, and processes for transporting therapeutic agents within the body to achieve optimal treatment outcomes (Zeeshan *et al*., 2017) [39]. The core concept of drug targeting is to concentrate the medication precisely at the intended site, thereby reducing its distribution in non-target regions. This targeted approach maximizes therapeutic efficacy while minimizing side effects from interactions with off-target sites, high doses, or unintended tissue exposure (Mahajan *et al*., 2007) [17]. Furthermore, targeting mitigates undesirable interactions between the drug and biological barriers that could impede its access to designated areas in the body (Vyas *et al*., 2004) [36].

Types of drug targeting in targeted drug delivery (TDD)

Targeted drug delivery (TDD) employs a range of innovative strategies to transport drugs precisely to specific body sites, enhancing therapeutic effects while limiting unintended impacts.

Active Drug Targeting

- **Receptor-Mediated Targeting:** Drug carriers bind to overexpressed receptors on target cells, concentrating drugs at sites like tumors.
- **Antibody-Drug Conjugates (ADCs):** Monoclonal antibodies deliver cytotoxic drugs to specific cells, enhancing precision and reducing toxicity.
- **Peptide-Drug Conjugates (PDCs):** Peptides linked to cytotoxic drugs target specific cell receptors for precise delivery.
- **Aptamers:** Single-stranded oligonucleotides bind specific proteins, enabling highly targeted drug delivery.

Passive Drug Targeting

Passive targeting leverages the intrinsic physical and chemical properties of both drug and target tissue to naturally guide the drug to its destination, utilizing mechanisms like:

- **Enhanced Permeability and Retention (EPR) Effect:** In tumor tissues characterized by leaky blood vessels and impaired lymphatic drainage, large molecules like nanoparticles accumulate effectively, amplifying drug presence at the tumor site.
- **Affinity-Based Targeting:** Here, a ligand attached to the drug delivery system binds selectively to specific receptors on the target cell, enabling precise drug entry.
- **Cell Surface Targeting:** By focusing on unique markers on target cell surfaces, this approach uses antibodies, aptamers, or other ligands for accurate targeting.

Vehicle or carrier system for TDD

Vehicles or carriers are engineered vectors that encapsulate or bond with drugs for targeted delivery, transporting, retaining, and delivering them to specific sites through structural modifications. Drug delivery (DD) technology has advanced by considering factors like bioavailability, pharmacokinetics, and timing for optimal delivery. Drug Delivery System require carriers such as micelles, liposomes, lipoprotein-based carriers, and NP-based carriers. Ideal carriers should be atoxic, non-immunogenic, biocompatible, biodegradable, and able to cross barriers and tumor vasculatures. Although no system fully meets these criteria, novel approaches continue to improve DD.

Commonly used carriers for TDD

There are different types of drug carriers, such as colloidals,

polymers, monoclonal Abs, NPs, and cell. The nature of the drug, the target, and the disease state determine the selection of the carrier to be used. Abs, proteins, lipoproteins, hormones, charged molecules, and polysaccharides are used with carriers as targeting moieties (Gujral *et al.*, 2013) [11].

Colloidal carrier system

Colloidal Drug Delievery Systems are nanoscale vesicles, including liposomes, niosomes, nanospheres, emulsions, and ceramics, that transport and release drugs near targets while modifying their distribution. They are classified as vesicular or microparticulate systems (Bhardwaj *et al*., 2011) [7].

Vesicular carrier system

Novel vesicular drug delivery systems aim to deliver drugs at controlled rates and specific sites based on treatment needs, with emerging carriers for targeted and controlled delivery (Biju *et al*., 2006) [8]. These systems enhance the therapeutic index, solubility, stability, and resistance to rapid drug degradation (Sunil *et al*., 2013) [29]. Nanosomes, including liposomes, niosomes, transferosomes, and ethosomes, are advanced vesicular carriers designed for targeted delivery. Each carrier generation differs in vesicular characteristics, preparation methods, storage, and therapeutic applications.

Liposomes

Liposomes are nanoscale lipoidal vesicles with a lipid bilayer structure enclosing an aqueous core, enabling entrapment of both hydrophilic and lipophilic drugs (Anwekar *et al*., 2011) [3]. They are synthesized for targeted oral, topical, and pulmonary delivery (Abu *et al*., 2001) [1]. Composed of natural/synthetic phospholipids, cholesterol, and polymer-conjugated lipids, liposomes reduce toxicity by using physiological lipids (Laouini *et al*., 2012; Vemuri *et al*., 1995) [15, 34]. They can be formulated as suspensions, dry powders, or gels and administered parenterally or topically (Laouini *et al*., 2012) [15].

Niosomes

Niosomes are nanoscale drug delivery systems with a bilayer of non-ionic surfactants, offering reduced toxicity and enhanced therapeutic effectiveness by targeting specific cells. While similar to liposomes in physicochemical properties, niosomes differ in composition, using surfactants instead of phospholipids. Niosomes are more stable and do not require special preparation or storage conditions, reducing production costs (Shukla *et al*., 2024) [24]. Liposomes and niosomes face limitations for transdermal delivery due to poor skin permeability, vesicle breakage, drug leakage, and aggregation. Transferosomes, a newer carrier system, overcome these issues and effectively deliver both low- and high-molecular weight drugs transdermally.

Transferosomes

Transferosomes are ultra-flexible lipid vesicles designed to penetrate skin without disruption. They have an aqueous core and a lipid bilayer with edge-activators like sodium cholate, Span 80, and Tween 80 to enhance deformability and skin penetration. These vesicles disrupt the stratum corneum's intercellular lipids, aiding drug delivery (Seema *et al*., 2012) [27]. They carry proteins, peptides (e.g., insulin), and vaccines, improving site specificity, drug safety, and reducing doses for skin diseases. Due to their flexibility, they effectively deliver nonsteroidal anti-inflammatory drugs like ibuprofen and diclofenac.

Ethosomes

Ethosomes are vesicular carriers with higher skin penetration than liposomes, used mainly for transdermal drug delivery. They contain phospholipids, alcohol (ethanol and isopropyl alcohol), and water, making them effective for hydrophilic and impermeable drugs (Seema *et al*., 2012) [27]. They often replace liposomes for transdermal delivery.

Ethosomes can help drugs penetrate the skin against the stratum corneum barrier. This is because some ethosomes fuse with the upper stratum corneum, while others rupture in the intercellular space to release the drug. Ethanol can also help ethosomes penetrate the skin because it interacts with the lipid molecules in the polar head group region, which lowers the transition temperature of the lipids. This increases fluidity, lowers lipid multilayer density, and gives the vesicles smoothness and flexibility (Pandey *et al.*, 2014) [24].

Polymeric carriers for TDDS

Polymers are macromolecules essential for advanced drug delivery systems, aiding in controlled and targeted drug release (Ravinder *et al*., 2014) [26]. Biodegradable polymer-based micro- and nanospheres enable controlled release at desired sites. Polymeric nanocarriers like poly (D, L-lactide-co-glycolide) show promising pharmacokinetics (Stevnovi *et al*., 2009) [28]. These carriers enhance hydrophobic drug solubility, reduce cytotoxicity, prolong circulation time, facilitate nanoparticle entry, and improve efficiency. While natural polymers like chitosan and dextran have been studied, synthetic polymers such as polyesters and polyamides dominate drug delivery research (Haijiao *et al*., 2016) [12].

Amphiphilic Polymers

Amphiphilic polymers with both hydrophilic and hydrophobic blocks are studied for drug delivery as micelles, nanomicelles, and dendrimers. By controlling the hydrophilic–hydrophobic balance, nanostructures like spherical micelles, cylindrical micelles, and vesicles are formed. Polymeric micelles have a hydrophobic core and hydrophilic shell for encapsulating hydrophilic drugs. Polymeric nanovesicles have a bilayer structure with an aqueous core for hydrophilic drugs and hydrophobic molecules in the membrane. These vesicles can deliver both hydrophilic and hydrophobic drugs, including anticancer drugs, genes, and proteins (Haijiao *et al*., 2016) [12].

Dendrimers

Dendrimers are monodispersed, multibranched polymeric carriers for drug targeting. They consist of a focal point, interior branching units, and exterior functional groups. Polar drugs are trapped by electrostatic interaction, while apolar drugs are captured through hydrophobic forces. Gene plasmids and nucleic acids can also bind electrostatically. Covalent linkage provides a more stable formulation, with drug release depending on the linkage type (Yousaf *et al*., 2019) [38].

Monoclonal Antibodies (mAbs)

Monoclonal antibodies (mAbs) are gaining attention as therapeutic agents for chronic conditions like cancer and

infectious diseases. They can be conjugated with chemotherapeutic drugs, radioisotopes, toxins, cytokines, and enzymes to target tumors and enhance cytotoxic effects.

- **High Specificity:** mAbs bind specifically to antigens on target cells, such as cancer cells or disease markers.
- **Selective Binding:** They selectively target diseased cells, minimizing off-target effects and protecting healthy tissues.
- **Facilitate Delivery:** mAbs can deliver therapeutic agents, including cytotoxic drugs or isotopes, directly to target cells.
- **Improve Pharmacokinetics:** mAbs enhance drug stability, prolong circulation time, and improve efficacy.
- **Immunomodulatory Effects:** mAbs can trigger immune responses like ADCC and CDC, boosting therapeutic efficacy.

Human mAbs, like adalimumab, are now approved for clinical use as antitumor agents (Kumar *et al*., 2017) [14].

Recent Advances

In recent years, micro sponges, solid-lipid NPs, and nano structured lipid carriers have been used and further investigated as carrier systems/vesicles for Drug Delievery System.

Microsponges

Microsponges are synthetic, biologically porous, inert polymers that can carry up to their own weight in drugs. They have the ability to protect the drug from the external environment and to provide controlled release. They have several applications especially in the field of skin care, they are used in cosmetics, sunscreen etc. They have been studied to dispense diclofenac to treat arthritis (Thakur *et al.*, 2015) [32].

Solid-lipid Nanoarticle

Solid lipid nanoparticles (SLNs) are colloidal carriers used for controlled release and delivery of active substances in pharmaceuticals, cosmetics, and food. They consist of a solid lipid matrix that encapsulates both lipophilic and hydrophilic drugs at room and body temperature.

SLNs offer advantages over traditional systems like liposomes and polymeric nanoparticles, including enhanced stability, controlled release, improved bioavailability, and biocompatibility. The lipid matrix typically includes triglycerides, fatty acids, waxes, or steroids. SLNs, sized between 50 and 1000 nm, can be administered orally, parenterally, topically, or via the pulmonary route.

Nanostructured lipid carriers

Nanostructured lipid carriers (NLCs) are an advanced lipid-based colloidal nanoparticle designed for drug delivery. They improve on solid lipid nanoparticles (SLNs) by offering better drug-loading capacity, controlled release, and stability. NLCs have a lipid matrix made of both solid lipids (e.g., triglycerides, fatty acids) and liquid lipids (e.g., oils, surfactants), unlike SLNs, which are entirely solid. This mixed structure prevents full crystallization, creating "nanostructured" regions that increase drug-loading capacity. The liquid lipids also enhance flexibility, stability, and prevent aggregation. NLCs improve drug solubility, bioavailability, targeted delivery, and reduce side effects. Surface modifications with ligands or stabilizers can further boost efficacy and biocompatibility.

Future Perspective

Theranostics Strategy

Theranostics is a medical approach that combines diagnostic and therapeutic capabilities into a single agent or procedure. The term "theranostics" itself is a blend of "therapy" and "diagnostics." The goal of theranostics is to provide personalized medicine by tailoring treatment to the individual patient's characteristics, such as their genetic makeup or the specific molecular features of their disease.

Precision Medicine

Precision medicine, also referred to as personalized or genomic medicine, is a medical approach that customizes treatment and prevention based on an individual's genetic makeup, environment, and lifestyle. The goal is to tailor healthcare decisions, therapies, practices, and products to each person, moving away from a generalized, one-size-fits-all method.

Nanomedicines to Nanorobots

Medical nanorobots are untethered nanostructures with engines that convert energy into mechanical forces to perform medical tasks. Due to their small size, they can interact with and penetrate cells, accessing cellular machinery. These nanorobots, used in cancer diagnosis and treatment, deliver payloads (drugs, genes, sensing molecules), perform biomedical functions (diagnosis, therapy), and target disease sites. They can be powered by external sources (NIR light, ultrasound, magnetic forces) or biological flow. Unlike nanocarriers, nanorobots have an active power system, making them distinct (Kong *et al*., 2023) [13].

Conclusion

Targeted drug delivery (TDD) heralds a transformative shift in medical science, offering unparalleled precision in delivering therapeutic agents to specific cells or tissues while drastically minimizing adverse effects. This innovative approach is redefining treatment paradigms, particularly for intricate conditions like cancer and cardiovascular diseases, by leveraging advanced mechanisms such as receptor-mediated targeting, antibody-drug conjugates, and the enhanced permeability and retention (EPR) effect. The rapid strides in nanotechnology have further catapulted TDD into the forefront of modern medicine, with clinically approved nanoparticles and cutting-edge delivery systems paving the way for a future dominated by personalized and highly efficient therapies. As TDD continues to evolve, it holds the blueprint for revolutionizing drug delivery, ensuring lower doses, minimal side effects, and unprecedented therapeutic precision.

References

1. Abu-Dahab R, Schafer UF, Lehr C. Lectin-functionalized liposomes for pulmonary drug delivery: effect nebulization on stability and bioadhesion. European Journal of Pharmaceutical Sciences. 2001;1:37-46.
2. Ali Y, Alqudah A, Ahmad S, Hamid SA, Farooq U. Macromolecules as targeted drugs delivery vehicles: an

overview. Designed Monomers and Polymers. 2015;22:91-97.
3. Anwekar H, Patel S, Singhai AK. Liposome as drug carrier. International Journal of Pharmaceutical and Life Sciences. 2011;2:945-951.
4. Bae YH, Park K. Targeted drug delivery to tumors: myths, reality and possibility. Journal of Controlled Release. 2011;153:198-205.
5. Barz M. Complexity and simplification in the development of nanomedicines. Nanomedicine (Lond). 2015;10(20):3093-3097.
6. Benyettou F, Motte L. Nanomedicine: towards the "magic bullet" science. Journal of Bioanalysis and Biomedicine. 2015;8:2.
7. Bhardwaj A, Kumar L. Colloidal drug delivery systems: a future prospective for treatment of tuberculosis. American Journal of PharmTech Research. 2011;1:102-123.
8. Biju S, Talegaonkar S, Mishra P, Khar K. Vesicular systems: an overview. Indian Journal of Pharmaceutical Sciences. 2006;68(2):141-153.
9. Fahmy TM, Fong PM, Goyal A, Saltzman WM. Targeted for drug delivery. Materials Today. 2005;8:18-26.
10. Gattani YS. Floating multiparticulate drug delivery systems: an overview. International Journal of Pharmaceutical and Biological Sciences. 2010;6:35-40.
11. Gujral S, Khatri S. A review on basic concept of drug targeting and drug carrier system. International Journal of Advances in Pharmaceutical and Biological Chemistry. 2013;2(1).
12. Haijiao L, Jingkang W, Ting W, Jian Z, Ying B, Hongxun H. Recent progress on nanostructures for drug delivery applications. Journal of Nanomaterials. 2016;2-9.
13. Kong X, Ga P, Wang J, Fang Y, Hwang KC. Advances of medical nanorobots for future cancer treatments. Journal of Hematology & Oncology. 2023;16:74.
14. Kumar A, Nautiyal U, Kaur C, Goel V, Piarchand N. Targeted drug delivery system: current and novel approach. International Journal of Pharmaceutical and Medical Research. 2017;5:448-454.
15. Laouini A, Jaafar-Maalej C, Limayem FH. Preparation, characterization and applications of liposomes: state of the art. Journal of Colloid Science and Biotechnology. 2012;149-166.
16. Li J, Wang Q, Xia G, Adilijiang N, Li Y, Hou Z, *et al*. Recent advances in targeted drug delivery strategy for enhancing oncotherapy. Pharmaceutics. 2023;15:2233.
17. Mahajan HS, Patil SB, Gattani SG, Kuchekar BS. Targeted drug delivery systems. Pharma Times. 2007;39(2).
18. Manzari MT, Shamay Y, Kiguchi H, Rosen N, Scaltriti M, Heller DA. Targeted drug delivery strategies for precision medicines. Nature Reviews Materials. 2021;6:351-70.
19. Mishra N, Pant P, Porwal A, Jaiswal J, Samad MA, Tiwari S. Targeted drug delivery: a review. American Journal of PharmTech Research. 2016;6.
20. Muller R, Keck C. Challenges and solutions for the delivery of biotech drugs: a review of drug nanocrystal technology and lipid nanoparticles. Journal of Biotechnology. 2004;113(1-3):151-170.
21. Muro S. Targeted drug delivery systems: achievements and challenges. Journal of Nanomedicine & Nanotechnology. 2012;3:1.
22. Nagoba SN, Warkari RD, Chandrawanshi MJ, Bhalekar RV, Viayjendra SSM. A review on targeted drug delivery. American Journal of PharmTech Research. 2018;8(4):2249-2287.
23. Öztürk K, Eroğlu H, Çalış S. Novel advances in targeted drug delivery. Journal of Drug Targeting. 2018;26:633-642.
24. Pandey V, Golhani D, Shukla R. Ethosomes: versatile vesicular carriers for efficient transdermal delivery of therapeutic agents. ResearchGate. 2014;1071-7544.
25. Rani K, Paliwal SA. Review on targeted drug delivery: its entire focus on advanced therapeutics and diagnostics. Scholars Journal of Applied Medical Sciences. 2014;2:328-331.
26. Ravinder K, Sukhvir K. Role of polymers in drug delivery. Journal of Drug Delivery and Therapeutics. 2014;4(3):32-36.
27. Seema M, Jadhav P, Manisha K, Vilasrao K. Novel vesicular system: an overview. Journal of Applied Pharmaceutical Science. 2012;2:193-202.
28. Stevanovic M, Uskokovic D. Poly(Lactide-co-glycolide)-based micro and nanoparticles for controlled drug delivery of vitamins. Current Nanoscience. 2009;5:1-15.
29. Sunil K, Vipin S, Nancy M, Suman B, Vikas J. Vesicular drug delivery systems: a novel approach for drug targeting. International Journal of Drug Delivery. 2013;121-30.
30. Tewabe A, Abate A, Tamrie M, Seyfu A, Siraj EA. Targeted drug delivery from magic bullet to nanomedicine: principles, challenges, and future perspectives. Journal of Multidisciplinary Healthcare. 2021;14:1711-1724.
31. Tiwari A, Tiwari V, Palaria B, Kumar M, Kaushik D. Microsponges: a breakthrough tool in pharmaceutical research. Future Journal of Pharmaceutical Sciences. 2022;8:31.
32. Thakur A, Roy A, Chatterjee S, Chakraborty P, Bhattacharya K, Mahata PP. Recent trends in targeted drug delivery. SMGroup. 2015.
33. Valent P, Groner B, Schumacher U. Paul Ehrlich (1854–1915) and his contributions to the foundation and birth of translational medicine. Journal of Innate Immunity. 2016;8:111-120.
34. Vemuri S, Rhodes C. Preparation and characterization of liposomes as therapeutic delivery systems: a review. Pharmaceutical Acta Helvetiae. 1995;70:95-111.
35. Vhora I, Patil S, Bhatt P, Gandhi R, Baradia D, Misra A. Receptor-targeted drug delivery: current perspective and challenges. Therapeutic Delivery. 2014;5:1007-24.
36. Vyas SP, Khar RK. Targeted & controlled drug delivery: novel carrier systems. New Delhi, India: CBS Publishers & Distributors; 2004.
37. Yoo J, Park C, Yi G, Lee D, Koo H. Active targeting strategies using biological ligands for nanoparticle drug delivery systems. Cancers. 2019;11:640.
38. Yousaf A, Ali A, Sadiq A, Shafida A, Umar F. Macromolecules as targeted drugs delivery vehicles: an overview. Designed Monomers and Polymers. 2019;22(1):91-97.

39. Zishan M, Zeeshan A, Faisal S. Vesicular drug delivery system used for liver diseases. World Journal of Pharmaceutical Sciences. 2017;5(4):28-35.
40. Kannagi R, Izawa M, Koike T, Miyazaki K, Kimura N. Carbohydrate-mediated cell adhesion in cancer metastasis and angiogenesis. Cancer Science. 2004;95:377-384.
41. Rabanel M, Aoun J, Elkin V, Mokhtar MI, Hildgen P. Drug-loaded nanocarriers: Passive targeting and crossing of biological barriers. Current Medicinal Chemistry. 2012;19(19):3070-3102.