ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

Review Article

([ISSN: xxxx-xxxx] Journal Homepage:https://anusearch-ijpas.com/)

Liposomes : For Control And Targeted Drug Delivery : A Comprehensive Review

Pavan K. Dhakne, Sahil R. Bagalkar, Harshal N. Rathod, Saurabh V. Jadhav, Shreyash M. Palaskar , Sahil D. Patil, Ramankit S. Jaiswal, Kailsh R. Biyani

ARTICLE INFO

Received On: 20-11-25

Modified On: 29-10-26

Published On: 17-09-26

DOI:
https://doi.org/10.5281/zenodo.20604366

ABSTRACT

Because of their unique physicochemical and structural characteristics, liposomes are an essential part of modern drug delivery systems. Extensive research has enhanced their formulation, stability, and targeting capabilities, leading to numerous therapeutic applications, particularly in oncology. One of their most important therapeutic properties is their ability to concentrate in malignant tissues through enhanced permeability and retention effect, which results in improved pharmacokinetics and less systemic toxicity. Two developments in liposomal engineering that have significantly enhanced tissue selectivity and pharmacokinetic properties while lowering off-target toxicity are PEGylation and ligand- based targeting. The current approach to drugs based on nanocarriers allows for multiple perspectives on targeted therapy. Liposomes prevent the processes that cause drug resistance while providing controlled or stimuli-responsive drug release. Current liposome research advancements are mostly focused on combination therapy, hybrid nanocarriers, and customized medicine applications. These advancements open up new possibilities for improved treatment outcomes, decreased systemic toxicity, and enhanced selectivity through more efficient site-specific drug delivery. Liposomes have become an important part of modern drug-delivery systems because of their unique physical and chemical properties. Their ability to carry both water-soluble and fat-soluble drugs, protect them from early degradation and deliver them safely to the target site has made liposomes highly useful, especially in cancer therapy. Over the years, continuous research has helped improve liposomal formulations, making

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

them more stable, more selective and better at controlling drug release. One of the major advantages of liposomes is their ability to increase drug concentration at diseased tissues by improving permeability and retention, while at the same time reducing side effects in healthy organs. Recent improvements such as PEGylation, ligand attachment and surface modification have further increased the circulation time of liposomes and enhanced their ability to reach specific cells or tissues. These advancements have allowed the development of controlled-release and stimuli-responsive liposomes that release the drug only when triggered by pH, temperature or enzymes. This helps avoid drug resistance and improves overall treatment results. Current studies also explore the use of hybrid nanocarriers that combine liposomes with other nanoparticles to improve stability, loading capacity and targeting efficiency. Such innovations open new possibilities for personalised medicine, safer drug delivery and better therapeutic outcomes. Overall, liposomal nanocarriers continue to evolve and play an essential role in delivering drugs more effectively, with reduced toxicity and improved patient safety.

KEYWORDS

nanoparticles, liposomes, Drug delivery system, Encapsulation, Controlled release, Nano carrier

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

INTRODUCTION

In the 1960s, Alec D. Bangham of the Babraham Institute at the University of Cambridge discovered liposomes. They consist of an aqueous compartment surrounded by one or more concentric lipid bilayers. The formulations, which were first made exclusively of natural lipids, can now include either natural or synthetic lipids as well as surfactants. Hydrophilic and lipophilic molecules can be trapped in the lipid membrane and aqueous core, respectively. The size of these nearly spherical lipid vesicles ranges from a few nanometers to many micrometers. However, the diameter of liposomes employed in medicine ranges from 50 to 450 nm. Liposomes seem to be an almost ideal drug-carrier system because they can store a wide range of compounds and resemble biological membranes in shape. Because of this, liposomes have been the subject of a great deal of research over the past fifty years and continue to do so today. They are valued for their biological and technological advantages as the best delivery systems for physiologically active chemicals, both in vitro and in vivo, and are thought to be the most successful drug-carrier system to date. Over the past 20 years, lipid

significant progress has been made, and several liposome-based biomedical applications are either in clinical trials or will soon be made available, while others have already been approved for widespread use. Therefore, rather than offering a thorough examination of the enormous volume of information that has been published on liposomes since their initial synthesis in the 1960s, the goal of this review is to draw attention to a few key topics that are essential to the development of liposomal formulations for therapy. We briefly examine the ways in which the size, surface charge, lipid architecture, and physicochemical properties of liposomes' membranes affect their efficacy. We also discuss how the physicochemical properties of liposomes influence their ability to penetrate various organs, their ability to circulate, their interactions with cells, and their final fate in vivo. In addition, we go over some of the strategies that

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

have been created to overcome the limitations of "first-generation" liposomes and how crucial they have been in clearing the way from the laboratory bench to clinical trials or the commercial market[1]. From an architectural and functional standpoint, liposomes are one of the most versatile supramolecular assemblies that science has discovered. Since extensive research on lipid vesicles started in 1965, they have made great progress, and their applications in a variety of domains, such as medicine and gene transfer, are well-established. In the analytical sciences, liposomes can be used as analytes, often in liposome production quality-assessment procedures, or as functional components in a variety of innovative analytical systems. For example, networks of liposomes linked by nanotubes have developed into ultrasmall-scale analytical tools, and the amplification provided by encapsulated markers is very beneficial for liposome immunoassays. This review discusses recent advancements in some of the most actively researched fields linked to liposomes[2]. Drug delivery systems (DDSs) can increase a medication's therapeutic index by enhancing drug concentration, residence time in target cells, and minimizing side effects. By transporting the potentially active medication to the site of action via a nano-vehicle, DDSs enhance the pharmacological properties of free medicines and conceal their drawbacks through better drug pharmacokinetics and biodistribution, as well as acting as drug reservoirs. These nanoparticles (NPs) usually varied in size from a few nanometers to several hundred nanometers, depending on their intended function. A range of natural, organic, and inorganic materials, including ceramic, metals, polymers, and lipids, are used to create NPs, which result in micelles and liposomes. The main way that therapeutic medications are included into NPs is through physical interactions like as entrapment, surface attachment, or encapsulation. The unique characteristics and differences of different NPs can be used to improve the aspects of traditional treatments. Nanomedicine facilitates the development of novel therapeutic options nanoscale range to provide a variety of active biomedical [3].

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

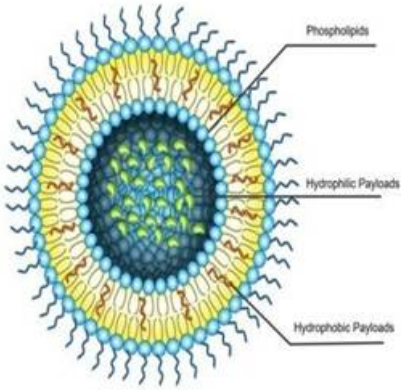


Fig.1 Liposome

Types of liposomes

1. Conventional Liposomes: These are simple liposomes made up of an aqueous core surrounded by lipid bilayers. Both hydrophilic and hydrophobic medications can be carried by them in the lipid bilayer and core, respectively.

2. Sterilized (PEGylated) Liposomes: These liposomes are stabilized by the polyethylene glycol (PEG) on their surface, which also decreases reticuloendothelial system (RES) uptake, lengthening the duration of circulation.

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

3. Ligand-Targeted Liposomes: Liposomes that have been altered by affixing ligands to their surface, such as peptides, carbohydrates, or antibodies, to enable targeted drug delivery by specifically targeting particular cell types.

4. Ph-sensitive liposomes are made to release their therapeutic cargo in reaction to acidic conditions, including intracellular compartments or tumor tissues.

5. Cationic Liposomes: Due to their effective interaction with negatively charged nucleic acids, these positively charged liposomes are frequently utilized in gene delivery.

6. Immunoliposomes: To target certain antigens, liposomes are coupled with antibodies or antibody fragments.

7. Stealth Liposomes (Cryptosomes): Usually PEGylated to avoid immunological detection, these particles have a longer half-life.

8. Multiple lipid bilayers divided by aqueous layers make up multilamellar vesicles (MLVs).

9. Single lipid bilayer vesicles with a tiny diameter are known as small unilamellar vesicles, or SUVs.

10. Niosomes: These have stability and bioavailability benefits since they are made from non-ionic surfactants rather than phospholipids[4].

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

MATERIALS AND METHODS

For this review, information was collected from trusted scientific sources to understand how liposomal drug-delivery systems have improved over the years. Research papers, review articles and clinical reports were searched mainly on PubMed, ScienceDirect, Google Scholar and other academic platforms. More focus was given to studies published in the last 15–20 years so that the review reflects the latest progress in liposome design and drug-delivery techniques. After collecting the papers, they were checked for usefulness, clarity of results and the type of liposomal advancement they discussed. The important points from these studies were then arranged, compared and explained in simple terms. This helped in creating a clear picture of how liposomal nanocarriers have developed, what benefits they offer and what challenges still remain.

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

RESULTS

Modern liposomal nanocarriers have several useful features that make them suitable for targeted and controlled drug delivery. They are generally safe, can carry different types of drugs and can release the medicine slowly over time. New techniques like surface coating (PEGylation), attaching targeting molecules and using liposomes that respond to heat, pH or light have improved their performance. These improvements help liposomes stay longer in the body, reach the disease site more effectively and reduce side effects. The review also covers how they are prepared, their physical and chemical properties, stability and their use in treating conditions like cancer, infections and genetic disorders. Overall, these features show how liposomes have become flexible and efficient tools for drug delivery.

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

DISCUSSION

Liposomal nanocarriers have emerged as a promising approach for improving drug delivery by enhancing stability, solubility, and targeted action of therapeutic agents. Recent advancements such as PEGylation and ligand-based surface modification have helped liposomes circulate longer in the bloodstream and reach specific tissues more effectively. The development of stimuli-responsive liposomes, which release drugs only under specific conditions like pH change, temperature rise, or enzyme activity, further strengthens their precision and reduces side effects. Moreover, the combination of liposomes with other nanocarriers and the shift toward personalized medicine have broadened their potential applications, especially in complex diseases such as cancer, infectious disorders, and neurological conditions. These innovations address major challenges related to biological barriers and drug resistance, demonstrating that liposomal systems can significantly improve therapeutic outcomes. Overall, continued research is expected to make these nanocarriers even more efficient, versatile, and clinically valuable.

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

CONCLUSION

In conclusion, advancements in liposomal nanocarriers have radically altered the field of controlled and targeted drug delivery. Because of their unique structural and physicochemical properties, liposomes are versatile vehicles that can encapsulate a range of therapeutic compounds. Two recent innovations that have enhanced tissue specificity, reduced off-target toxicity, and lengthened circulation time are PEGylation and ligand-based targeting. The development of stimuli-responsive liposomes, which are triggered by pH, temperature, or enzyme activity and enable precise, site-specific drug release, addresses a variety of problems with conventional delivery methods. Furthermore, applications of personalized medicine and integration with hybrid nanocarriers offer exciting opportunities for safer and more effective customized treatments. By tackling significant biological barriers and drug resistance mechanisms, these nanocarriers enhance their utility in cancer, infectious diseases, neurological disorders, and gene therapy. As research progresses, liposomal nanocarriers continue to evolve into reliable, versatile platforms, paving the way for next-generation therapies with improved

ABBREVIATIONS

(DRV) - Dehydration–rehydration vesicles

FUNDING

non

CONFLICT OF INTERESTS

Autor does not show any conflict of interest

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

REFERENCES

1. Bozzuto G, Molinari A. Liposomes as nanomedical devices. International journal of nanomedicine. 2015 Feb 2:975-99.

2. Jesorka A, Orwar O. Liposomes: technologies and analytical applications. Annu. Rev. Anal. Chem.. 2008 Jul 19;1(1):801-32.

3. Nsairat H, Khater D, Sayed U, Odeh F, Al Bawab A, Alshaer W. Liposomes: structure, composition, types, and clinical applications. Heliyon. 2022 May 1;8(5).

4. Guimarães D, Cavaco-Paulo A, Nogueira E. Design of liposomes as drug delivery system for therapeutic applications. International journal of pharmaceutics. 2021 May 15;601:120571.

5. Lombardo D, Kiselev MA. Methods of liposomes preparation: formation and control factors of versatile nanocarriers for biomedical and nanomedicine application. Pharmaceutics. 2022 Feb 28;14(3):543.

6. Lombardo D, Kiselev MA. Methods of liposomes preparation: formation and control factors of versatile nanocarriers for biomedical and nanomedicine application. Pharmaceutics. 2022 Feb 28;14(3):543.

7. Kihwan Choi, Alphonsus H.C. Ng, Ryan Fobel and Aaron R. Wheeler Vol. 5 (2012), pp. 413–440

8. Byoung-Yong Chang and Su-Moon Park Vol. 3 (2010), pp. 207–229

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

9. Eun Jeong Cho, Joo-Woon Lee and Andrew D. Ellington Vol. 2 (2009), pp. 241–264

10. Liu P, Chen G, Zhang J. A review of liposomes as a drug delivery system: current status of approved products, regulatory environments, and future perspectives. Molecules. 2022 Feb 17;27(4):1372.

11. Liu P, Chen G, Zhang J. A review of liposomes as a drug delivery system: current status of approved products, regulatory environments, and future perspectives. Molecules. 2022 Feb 17;27(4):1372.

12. Nour E.M., El-Habashy S.E., Shehat M.G., Essawy M.M., El-Moslemany R.M., Khalafallah N.M. Atorvastatin liposomes in a 3D-printed polymer film: A repurposing approach for local treatment of oral candidiasis. Drug Deliv. Transl. Res. 2023;13:2847–2868. doi: 10.1007/s13346-023-01353-4.

13. Sawant R.R., Torchilin V.P. Challenges in Development of Targeted Liposomal Therapeutics. AAPS J. 2012;14:303–315. doi: 10.1208/s12248-012-9330-0.

14. Cristaldi D.A., Labanca A., Pottinger T.D., Owen J., Stulz E., Zhang X., Carugo D. 3D printed reactor-in-a-centrifuge (RIAC): Making flow-synthesis of nanoparticles pump-free and cost-effective. Chem. Eng. J. 2021;425:130656. doi: 10.1016/j.cej.2021.130656.

15. Rahali K., Tabriz A.G., Douroumis D. The effect of 3D printed microfluidic array designs on the preparation of liposome nanoparticles. J.

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES

HOW TO CITE: Pavan K. Dhakne, Sahil R. Bagalkar, Harshal N. Rathod, Saurabh V. Jadhav, Shreyash M. Palaskar , Sahil D. Patil, Ramankit S. Jaiswal, Kailsh R. Biyani, *Liposomes : For Control And Targeted Drug Delivery : A Comprehensive Review*, Anusearch IJPAS, 2026, I(I), Page, Review Article, DOI: https://doi.org/10.5281/zenodo.20604366

ANU-SEARCH THE INTERNATIONAL JOURNAL OF PHARMA AND ALLIED SCIENCES