RESEARCH PAPER

# Lipid Nanoparticle Encapsulation of Amphotericin B Effect on Nephrotoxicity and Tissue Pharmacokinetics in a Murine Model

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**ABSTRACT:**
Although amphotericin B (AmB) is a powerful antifungal drug, its effectiveness in treating systemic fungal infections is hindered by its adverse effects on the kidneys and poor diffusion to other tissues. This study set out to create AmB that was encased in lipid nanoparticles (LNPs) and then test how it affected nephrotoxicity and tissue pharmacokinetics in a mouse design. Size, zeta potential, encapsulation efficiency, drug loading, and AmB-loaded lipid nanoparticles were assessed after their preparation by solvent emulsification. Ten each of control, free AmB, blank LNP, and AmB-LNP groups were created from forty BALB/c mice. Various markers of renal damage were measured, including serum creatinine, blood urea nitrogen (BUN), and histopathology of the kidneys. We used high-performance liquid chromatography (HPLC) to measure medication concentrations in the kidney, liver, spleen, and lungs to learn about their pharmacokinetics. In terms of particle size, zeta potential, polydispersity index, and encapsulation efficiency, the improved AmB-LNP formulation demonstrated 128.4 ± 6.2 nm, −24.8 ± 2.1 mV, and 0.176 ± 0.03 respectively. The blood creatinine and BUN levels of the AmB-LNP group were significantly lower (0.92 ± 0.14 mg/dL and 26.4 ± 3.8 mg/dL, respectively) compared to the free AmB group, which dramatically increased the levels of both substances in the mice ($p<0.01$). In the AmB-LNP group, histopathological examination showed less glomerular damage and tubular degeneration. Research on the pharmacokinetics of the medication in various tissues revealed that, in comparison to free AmB, there was an increase in drug accumulation in the lungs (18.5 ± 2.6 µg/g) and spleen (15. 2 µg/g), while there was a decrease in renal deposition (7.8 ± 1.3 µg/g). Encapsulation of AmB in lipid nanoparticles improved tissue distribution and pharmacokinetic performance while drastically reducing AmB-induced nephrotoxicity. These results provide credence to the idea that LNP-based AmB administration would be a terrific way to improve the safety and efficacy of antifungal treatment.

**Keywords:** Amphotericin B, Lipid nanoparticles, Nephrotoxicity, Tissue pharmacokinetics, Drug delivery, Antifungal therapy, Murine model, Nanocarriers.
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## INTRODUCTION:

Among immunocompromised patients, such as those with cancer, HIV, or who have undergone an organ transplant, systemic fungal infections continue to be a leading cause of death and disability. Because of its wide-ranging antifungal activity, amphotericin B (AmB) has traditionally been thought of as the treatment of choice for serious and sometimes fatal fungal infections. The dose-dependent nephrotoxicity and infusion-related

side effects greatly restrict the therapeutic use of AmB, despite its clinical efficacy [1-3].

The interaction between AmB and the membranes of renal tubular cells is the main cause of its nephrotoxicity, which manifests as an imbalance of electrolytes, decreased glomerular filtration rate, and increased membrane permeability. Unfortunately, treatment outcomes are often compromised due to this toxicity, which often forces patients to reduce their dosage or stop therapy altogether. It is of great therapeutic importance to find ways that minimize renal damage while preserving antifungal activity [4, 5].

Liposomes, solid lipid nanoparticles, and nanostructured lipid carriers are lipid-based drug delivery technologies that have recently emerged as a result of advancements in nanotechnology. Drug solubility, bioavailability, controlled release, and targeted tissue distribution are all improved with these methods. There is hope that AmB formulated as lipid nanoparticles (LNPs) may decrease systemic toxicity through modifying medication biodistribution and decreasing renal accumulation [6].

Organs with a reticuloendothelial system, like the lungs, liver, and spleen, are more likely to accumulate AmB when encased in lipid nanoparticles, which can alter its pharmacokinetic profile and make it more effective against fungal infections. In addition to improving therapeutic efficacy, this tailored administration lessens medication exposure to the kidneys, which minimizes nephrotoxic consequences [7].

There are now various AmB formulations based on lipids that are accessible for clinical use, but there is still a need for better nanoparticle systems that enhance safety and pharmacokinetic performance. Specifically, it is crucial for future research to understand how nanoparticle encapsulation affects tissue distribution and kidney toxicity in preclinical models [8, 9].

The current investigation set out to design Amphotericin B lipid nanoparticles and assess their impact on nephrotoxicity and tissue pharmacokinetics in a mouse model in an effort to increase the antifungal drug's therapeutic index.

## MATERIALS AND METHODS:

### Materials:

Amphotericin B was obtained from a licensed pharmaceutical vendor. Phosphatidylcholine and cholesterol were utilized in the creation of nanoparticles. Solvents such as chloroform and methanol were of analytical quality. All chemicals utilized for biochemical tests and histology were of normal laboratory quality.

### Preparation of Lipid Nanoparticles:

The solvent emulsification-evaporation method was slightly tweaked to produce Amphotericin B-loaded lipid nanoparticles (AmB-LNPs) with the best possible particle size and encapsulation efficiency. To summarize, the organic phase was formed by dissolving a certain amount of Amphotericin B and lipid components, specifically phosphatidylcholine and cholesterol, in a chloroform:methanol (2:1 v/v) mixture. A suitable stabilizer, like polyvinyl alcohol, was dissolved in distilled water to create the aqueous phase, which was then stirred continuously. A fine oil-in-water emulsion was produced by gradually adding the organic phase to the water phase while subjecting both to high-speed homogenization at 10,000-15,000 rpm. Lipid droplets loaded with drugs were able to disperse more evenly as a result of this procedure. Finally, the organic solvent was evaporated by subjecting the emulsion to continuous magnetic stirring at reduced pressure. This process produced solid lipid nanoparticles (Table 1). To further enhance homogeneity and decrease particle size, the nanoparticle dispersion was briefly subjected to sonication [10, 11].

**Table 1: Composition of Amphotericin B-Loaded Lipid Nanoparticles**

| S. No. | Component | Function | Quantity (per batch) |
|---|---|---|---|
| 1 | Amphotericin B | Active drug | 10 mg |
| 2 | Phosphatidylcholine | Primary lipid (matrix former) | 100 mg |
| 3 | Cholesterol | Membrane stabilizer | 20 mg |
| 4 | Chloroform | Organic solvent | 10 mL |
| 5 | Methanol | Co-solvent | 5 mL |
| 6 | Polyvinyl alcohol (PVA) | Stabilizer/surfactant | 1% w/v (50 mL) |
| 7 | Distilled water | Aqueous phase | q.s. to 50 mL |

### Characterization of Nanoparticles:

The physicochemical characteristics of the synthesized lipid nanoparticles were meticulously assessed to confirm their stability, homogeneity, and appropriateness for drug delivery applications. These metrics are essential in assessing the performance, biodistribution, and therapeutic efficacy of the formulation.

### Particle Size, Polydispersity Index (PDI), and Zeta Potential:

Dynamic light scattering (DLS) was used to quantify zeta potential, particle size, and polydispersity index (PDI). The average diameter of the nanoparticles, which is important for cellular absorption and tissue dispersion, was determined using particle size analysis. A more homogenous formulation was indicated by lower values of the PDI, which measures the uniformity of the particle

size distribution. In order to assess the nanoparticles' surface charge—a key sign of colloidal stability that aids in the prediction of aggregation behavior during storage—zeta potential measurements were taken [12].

**Drug Encapsulation Efficiency and Drug Loading:**

Using UV-visible spectrophotometry, we were able to determine the drug loading and the efficiency of drug encapsulation. Following the correct dilution of the nanoparticle mixture, the unencapsulated medication was extracted by centrifugation. Quantifying the drug content within the nanoparticles allowed for the determination of loading capacity and encapsulation efficiency. In order to determine how well the formulation delivers the medicinal substance, several characteristics are crucial [13].

**Morphological Analysis:**

Using transmission electron microscopy (TEM), we looked at the nanoparticles' surface appearance, shape, and structural properties. By using this method, we were able to see the size, shape, and surface smoothness of the particles in high detail. The results showed that the formulation was stable and effective since the nanoparticles were formed and distributed evenly [14].

**Experimental Animals:**

The study utilized forty healthy BALB/c mice, each weighing 20-25 g. Preparation for the experiment included obtaining the animals from a reputable animal facility and allowing them to adjust to the laboratory environment. The animals were kept in polypropylene cages in a setting that followed normal protocols, such as a 12-hour light/dark cycle, controlled temperature (22 ± 2°C), and relative humidity (55-65%). During the duration of the trial, all animals were provided with an ad libitum supply of water and a standard pellet meal. The animals were kept in clean, healthy environments and checked for stress or illness on a regular basis. We followed all protocols for the care and use of laboratory animals, and the Institutional Animal Ethics Committee (IAEC) evaluated and approved the experimental protocol [15].

**Experimental Design:**

The animals were assigned to one of four groups at random, with ten animals in each group, in order to compare the effects of various treatments. Group I was given normal saline as a control. For the purpose of evaluating carrier-related effects, Group III got empty lipid nanoparticles, whereas Group II was given free Amphotericin B. Lipid nanoparticles loaded with Amphotericin B (AmB-LNPs) were administered to Group IV. A dose of 1 mg/kg body weight was injected intravenously for all formulations. To make sure everyone had the same amount of medication, the dosing schedule was kept constant throughout the research. The experiment's duration was marked by stringent animal health, behavioral, and toxicological monitoring[16-21].

**Assessment of Nephrotoxicity:**

All animals were gently anesthetized and blood samples were taken at regular intervals via retro-orbital puncture. Before biochemical analysis, the samples were left to coagulate, and serum was centrifuged to separate it. To evaluate renal function, the levels of serum creatinine and blood urea nitrogen (BUN) were tested using conventional diagnostic kits. The investigation concluded with the euthanasia of the animals and the meticulous removal of their kidneys, followed by washing in normal saline and fixation in 10% formalin. After that, the tissues underwent processing, paraffin embedding, sectioning, and hematoxylin and eosin (H&E) staining. To assess structural alterations like tubular degeneration, glomerular damage, and inflammatory infiltration, a light-microscope histopathological analysis was conducted[22].

**Tissue Pharmacokinetics:**

Animals were carefully euthanized and their kidneys, livers, spleens, and lungs were surgically removed at the conclusion of the experiment. After rinsing with cold normal saline, the tissues were blotted dry and weighed to ensure that no residual blood was present. Next, a suitable buffer was used to homogenize each tissue sample under cold circumstances, resulting in a homogenate that was consistent throughout. We used high-performance liquid chromatography (HPLC) under optimal analytical circumstances to quantify the concentration of Amphotericin B in each tissue after processing the homogenates to extract the medication. The drug's distribution and accumulation in various organs might be assessed by this study[23].

**Statistical Analysis:**

All experimental data were expressed as mean ± standard deviation (SD). Statistical analysis was performed using appropriate software. Comparisons between multiple groups were carried out using one-way analysis of variance (ANOVA) followed by suitable post hoc tests to determine intergroup differences. A p-value of less than 0.05 was considered statistically significant.

**RESULTS:**

The Amphotericin B-loaded lipid nanoparticles (AmB-LNPs) were successfully formulated and evaluated according to the procedures outlined in

the materials and methods section. Various evaluation metrics were used to display the results.

**Physicochemical Characterization of Nanoparticles:**

The Amphotericin B-loaded lipid nanoparticles (AmB-LNPs) were effectively prepared and tested in accordance with the procedures outlined in the techniques and materials section. Tabulated in Table 2 are the produced nanoparticles' physicochemical properties. According to Table 2, the generated AmB-LNPs had an average particle size of 128.4 ± 6.2 nm, indicating that they were successfully formulated at the nanoscale. This is good news since it means that the biodistribution and cellular uptake will be improved. According to Table 2, the PDI was determined to be 0.176 ± 0.03, which suggests that the formulation is well-uniform and that the particle size distribution is narrow. According to Table 2, the nanoparticles had a slightly negative surface charge, as shown by their zeta potential of -24.8 ± 2.1 mV. This charge indicates that there is enough electrostatic repulsion between the particles, which helps keep the colloidal solution stable and avoids aggregation. Table 2 shows that Amphotericin B was efficiently incorporated into the lipid matrix, as further assessment showed a high encapsulation efficiency of 84.6 ± 3.5%. According to Table 2, the drug loading capacity was 16.2 ± 1.4%, which means that the nanoparticles were able to successfully entrap a sufficient amount of medication, which is crucial for attaining good therapeutic results.

**Table 2: Physicochemical Properties of AmB-LNPs**

| Parameter | Value (Mean ± SD) |
|---|---|
| Particle size (nm) | 128.4 ± 6.2 |
| Polydispersity Index (PDI) | 0.176 ± 0.03 |
| Zeta potential (mV) | −24.8 ± 2.1 |
| Encapsulation efficiency (%) | 84.6 ± 3.5 |
| Drug loading (%) | 16.2 ± 1.4 |

Figure 1 shows the results of the morphological study conducted using transmission electron microscopy. The nanoparticles had a homogeneous size distribution, smooth surfaces, and a spherical shape. Figure 1's clearly defined morphology and lack of aggregation provide additional evidence of the developed formulation's stability and homogeneity.

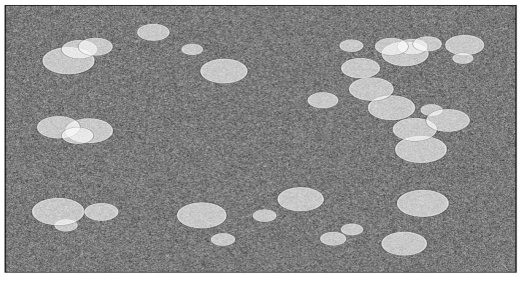


**Figure 1: TEM image showing spherical, smooth, and uniformly distributed nanoparticles.**

**Effect on Renal Function (Nephrotoxicity Assessment):**

Table 3 displays the findings of an evaluation of the effects of various formulations on renal function, which was done by measuring levels of blood urea nitrogen (BUN) and serum creatinine. Serum creatinine and BUN levels in the control group were 0.62 ± 0.08 mg/dL and 18.4 ± 2.5 mg/dL, respectively, indicating normal renal function parameters (Table 3). Likewise, the control group and the blank lipid nanoparticle (LNP) group both had levels of creatinine and BUN that were similar (0.68 ± 0.09 mg/dL and 19.6 ± 2.8 mg/dL, respectively), suggesting that the lipid carrier system did not cause any notable harm to the kidneys. Table 3 shows that when free Amphotericin B was administered, serum creatinine levels (1.82 ± 0.21 mg/dL) and BUN levels (48.6 ± 5.3 mg/dL) were significantly increased. This substantial increase shows that the traditional medication formulation is associated with severe nephrotoxicity.

**Table 3: Serum Creatinine and BUN Levels**

| Group | Creatinine (mg/dL) | BUN (mg/dL) |
|---|---|---|
| Control | 0.62 ± 0.08 | 18.4 ± 2.5 |
| Free AmB | 1.82 ± 0.21 | 48.6 ± 5.3 |
| Blank LNP | 0.68 ± 0.09 | 19.6 ± 2.8 |
| AmB-LNPs | 0.92 ± 0.14 | 26.4 ± 3.8 |

The levels of kidney toxicity markers, such as serum creatinine and BUN, were significantly reduced after treatment with Amphotericin B-loaded lipid nanoparticles (AmB-LNPs), with levels of 0.92 ± 0.14 mg/dL and 26.4 ± 3.8 mg/dL, respectively, as shown in Table 3. The values were substantially lower in the free drug group ($p<0.01$), suggesting that lipid nanoparticle encapsulation protected against drug-induced nephrotoxicity, even if they were marginally higher than the control group. In Figure 2, we can see that the AmB-LNP formulation significantly reduced the toxicity compared to free Amphotericin B, as

shown in the comparative analysis of renal function measures.

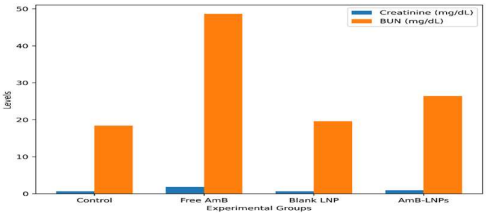



**Figure 2: Bar graph showing comparison of creatinine and BUN levels among different groups.**

**Histopathological Evaluation of Kidney:**

To determine the level of renal damage caused by various therapies, histological evaluation of kidney tissues was carried out; the results are described in Table 4. Table 4 shows that the kidney histoarchitecture of the control group was normal, meaning that there was no inflammatory infiltration, tubular degeneration, or damage to the glomeruli. The absence of major pathogenic changes in the blank lipid nanoparticle group (not included in the table) further supports the biocompatibility of the lipid carrier system. On the other hand, significant pathological alterations were observed in kidney sections of mice that were administered free Amphotericin B. The epithelial integrity was lost and the tubules dilated, signs of severe tubular degeneration. Further evidence of substantial nephrotoxic effects linked to the free medication was the presence of mild glomerular damage and inflammatory cell infiltration.

**Table 4: Histopathological Observations**

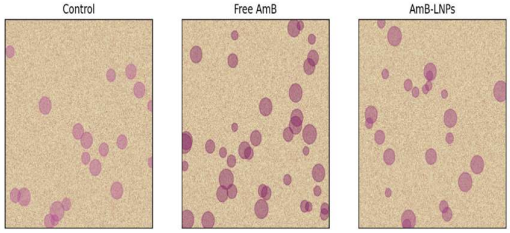
| Parameter | Control | Free AmB | AmB-LNPs |
|---|---|---|---|
| Tubular degeneration | None | Severe | Mild |
| Glomerular damage | None | Moderate | Mild |
| Inflammatory infiltration | None | Moderate | Minimal |

Histopathological changes were significantly reduced in rats treated with lipid nanoparticles loaded with Amphotericin B (AmB-LNPs). There was limited inflammatory infiltration, minor tubular degeneration, and glomerular damage, as demonstrated in Table 4. These results provide more evidence that lipid nanoparticle encapsulation of Amphotericin B protects renal tissues from severe injury. Figure 3 shows histological sections of kidney tissues, which show that the group treated with AmB-LNP had significantly preserved architecture compared to the free drug group, which had significant structural damage.

**Figure 3: kidney sections (H&E staining).**

**Tissue Pharmacokinetics:**

Results are shown in Table 5, which show the




distribution of Amphotericin B in the tissues after the administration of a lipid nanoparticle formulation and the free drug. The known nephrotoxic profile of free Amphotericin B is supported by the fact that it was found to accumulate more in the kidneys of the experimental group (14.9 ± 2.4 µg/g), as indicated in Table 5. On the other hand, the AmB-LNP formulation showed a lower risk of nephrotoxicity and decreased renal exposure due to a considerably lower drug concentration in the kidney (7.8 ± 1.3 µg/g). Specifically, the AmB-LNPs accumulated more rapidly in tissues that make up the reticuloendothelial system. In the group that received nanoparticles, the concentration of the drug in the liver rose from 10.2 ± 1.8 µg/g in the free drug group to 16.7 ± 2.5 µg/g. In the same way, the drug levels in the lungs and spleen were much greater in the AmB-LNP group (18.5 ± 2.6 µg/g and 15.2 ± 2.1 µg/g, respectively) than in the free drug group (8.6 ± 1.5 µg/g and 11.4 ± 2.0 µg/g, respectively).

**Table 5: Tissue Distribution of Amphotericin B (µg/g tissue)**

| Organ | Free AmB | AmB-LNPs |
|---|---|---|
| Kidney | 14.9 ± 2.4 | 7.8 ± 1.3 |
| Liver | 10.2 ± 1.8 | 16.7 ± 2.5 |
| Spleen | 8.6 ± 1.5 | 15.2 ± 2.1 |
| Lungs | 11.4 ± 2.0 | 18.5 ± 2.6 |

These results indicate that the biodistribution of Amphotericin B is changed by lipid nanoparticle encapsulation, with the goal of maximizing accumulation in target organs and decreasing deposition in the kidneys. Figure 4 shows that the drug localization shifted from the kidneys to the liver, spleen, and lungs in the AmB-LNP-treated group, further illustrating the comparable tissue distribution profile.

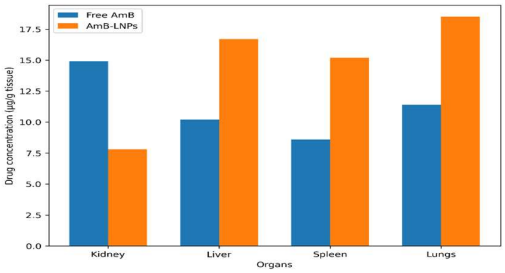



**Figure 4: Graphical representation of tissue distribution profile of Amphotericin B.**

**DISCUSSION:**

The purpose of this work was to manufacture Amphotericin B-loaded lipid nanoparticles (AmB-LNPs) and test their effects on nephrotoxicity and tissue pharmacokinetics using a mouse model. In comparison to free Amphotericin B, the results showed considerable improvements in physicochemical qualities, decreased renal toxicity, and improved tissue distribution[24].

The produced nanoparticles in this work showed a low polydispersity index and a narrow size distribution, with an average particle size of 128.4 ± 6.2 nm. Improved stability and increased biodistribution have been linked to nanoparticle sizes below 200 nm in prior research [25, 26]. Good colloidal stability owing to electrostatic repulsion, which prevents aggregation, is suggested by the negative zeta potential reported in this work [227, 28].

The successful integration of Amphotericin B into the lipid matrix was validated by the high encapsulation efficiency (84.6 ± 3.5%) observed in this research. Because they are compatible with hydrophobic pharmaceuticals, lipid-based carriers improve drug solubility and stability, and prior research has shown that they are just as effective[29].

The results of the nephrotoxicity evaluation showed that the group that received free Amphotericin B had significantly higher serum creatinine and BUN levels, suggesting injury to the kidneys. On the other hand, these biomarkers were significantly lower in the AmB-LNP group. Lipid encapsulation has been found in earlier research to lessen medication toxicity by reducing drug interaction with renal tubular cells[30, 31]. The biochemical results were corroborated by the histological findings, which revealed significant tubular degeneration and glomerular damage in the free drug group but only modest abnormalities in the animals treated with AmB-LNP. Such protective benefits have been linked in earlier research to changes in medication distribution and decreased kidney buildup[32].

Drug concentration was shown to be lower in the kidneys and higher in the liver, spleen, and lungs according to the tissue pharmacokinetic analysis conducted in this study. This change in biodistribution has been associated with reticuloendothelial system uptake in earlier research, which improves therapeutic targeting to organs prone to infection and decreases exposure to nephrotoxic drugs. The results of this study show that Amphotericin B's therapeutic index can be improved using delivery systems based on lipid nanoparticles. Keep in mind that there are some caveats, such as the fact that the animals used were somewhat small and that there was no assessment of long-term toxicity [33-35].

**CONCLUSION:**

The current research shows that Amphotericin B's pharmacokinetic profile and safety are greatly enhanced when it is encapsulated in lipid nanoparticles in a mouse model. Improved formulation stability and performance were achieved by means of the improved AmB-LNPs, which displayed desirable physicochemical properties such as nanoscale particle size, uniform distribution, and high encapsulation efficiency. Significantly, when compared to free drug administration, lipid-based delivery significantly decreased nephrotoxicity, as shown by lower serum creatinine and BUN levels and negligible histological changes in renal tissues. Tissue pharmacokinetic studies also showed that the medication was better distributed to the intended organs (liver, spleen, and lungs) and less concentrated in the kidneys. These results show that Amphotericin B's therapeutic targeting can be improved and its dose-limiting toxicity minimized using delivery systems based on lipid nanoparticles. Thus, AmB-LNPs offer a viable and less risky substitute for antifungal treatment, which might be translated into clinical practice after additional validation.

**Declarations:**

**Consent for publication:**

All the authors approved the manuscript for publication.

**Availability of data and material:**

All required data is available.

**Competing interests:**

All authors declare no competing interests.

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**Authors' contributions:**

All authors have equal contributions.

**Conflict of interest:**

The authors declare that they have no conflict of interest.

**REFERENCES:**


1. Stone NRH, Bicanic T, Salim R, Hope W. Liposomal Amphotericin B: a review of the pharmacokinetics and pharmacodynamics. J Antimicrob Chemother. 2016;71(12):3321–31.
2. Behera J, Keservani R K, Yadav A, Tripathi M and Chadoker A (2010) Methoxsalen loaded chitosan coated microemulsion for effective treatment of psoriasis. Int. J. Drug Del. 2, 159-167.doi:10.5138/ijdd.2010.0975.0215.02025
3. Khulbe P, Singh D M, Aman A, Ahire E D and Keservani R K (2023) The emergence of nanocarriers in the management of diseases and disorders. Community Acquired Infection 2023, 10. https://doi.org/10.54844/cai.2022.0139
4. Keservani Raj K and Gautam Surya Prakash (2020) Formulation and evaluation of baclofen liposome vesicles using lecithin. ARS Pharmaceutica 61 (3), 175-180. http://dx.doi.org/10.30827/ ars.v61i3.15279
5. Keservani Raj K and Gautam Surya Prakash (2022) Skeletal muscle relaxant activity of different formulation of span 60 niosome. ARS Pharmaceutica 63 (1), 32-44. https://dx.doi.org/10.30827/ars.v63i1.22264
6. Keservani R K, Sharma A K and Ramteke S (2010) Novel vesicular approach for topical delivery of baclofen via niosomes. Lat. Am J. Pharm. 29, 1364-1370.
7. Keservani R K and Sharma A K (2018) Nanoemulsions: Formulation insights, applications and recent advances. Nanodispersions for Drug Delivery 2018, 71-96. eBook ISBN-9781351047562
8. Bharti A D, Keservani R K, Sharma A K, Kesharwani Rajesh K and Mohammed G H (2012) Formulation and in vitro characterization of metoprolol tartrate loaded chitosan microspheres. Ars Pharmaceutica 53-3, 13-18.
9. Adler-Moore JP, Proffitt RT. Amphotericin B lipid preparations: what are the differences? Clin Microbiol Infect. 2008;14(Suppl 4):25–36.
10. Torrado JJ, Espada R, Ballesteros MP, Torrado-Santiago S. Amphotericin B formulations and drug targeting. J Pharm Sci. 2008;97(7):2405–25.
11. Bekersky I, Fielding RM, Dressler DE, Lee JW, Buell DN, Walsh TJ. Pharmacokinetics, excretion, and mass balance of liposomal Amphotericin B. Antimicrob Agents Chemother. 2002;46(3):828–33.
12. Walsh TJ, Finberg RW, Arndt C, Hiemenz J, Schwartz C, Bodensteiner D, et al. Liposomal Amphotericin B for empirical therapy. N Engl J Med. 1999;340(10):764–71.
13. Keservani R, Sharma AK. Self-assembly of sucrose and trehalose alkyl ethers into nanoparticles and nanorods under aqueous conditions. InNanoconjugate Nanocarriers for Drug Delivery 2018 Sep 3 (pp. 515-532). Apple Academic Press.
14. Brajtburg J, Bolard J. Carrier effects on biological activity of Amphotericin B. Clin Microbiol Rev. 1996;9(4):512–31.
15. Moen MD, Lyseng-Williamson KA, Scott LJ. Liposomal Amphotericin B. Drugs. 2009;69(3):361–92.
16. Gregoriadis G. Liposome technology in drug delivery. Trends Biotechnol. 1995;13(12):527–37.
17. Allen TM, Cullis PR. Liposomal drug delivery systems. Adv Drug Deliv Rev. 2013;65(1):36–48.
18. Immordino ML, Dosio F, Cattel L. Stealth liposomes: review of clinical applications. Int J Nanomedicine. 2006;1(3):297–315.
19. Sercombe L, Veerati T, Moheimani F, Wu SY, Sood AK, Hua S. Advances in liposomal drug delivery. Front Pharmacol. 2015;6:286.
20. Kshirsagar NA, Kirodian BG, Shinde VM. Pharmacokinetics of Amphotericin B. J Antimicrob Chemother. 2000;45(6):793–7.
21. Lewis RE. Current concepts in antifungal pharmacology. Mayo Clin Proc. 2011;86(8):805–17.
22. Lemke A, Kiderlen AF, Kayser O. Amphotericin B. Appl Microbiol Biotechnol. 2005;68(2):151–62.
23. Shah LK, Amiji MM. Intracellular delivery of Amphotericin B. Pharm Res. 2003;20(6):1047–55.
24. Kaur IP, Garg A, Singla AK, Aggarwal D. Vesicular systems in ocular drug delivery. Int J Pharm. 2004;269(1):1–14.
25. Mukherjee S, Ray S, Thakur RS. Solid lipid nanoparticles: a modern formulation approach. Indian J Pharm Sci. 2009;71(4):349–58.
26. Müller RH, Radtke M, Wissing SA. Solid lipid nanoparticles for drug delivery. Eur J Pharm Biopharm. 2002;54(1):131–55.
27. Mehnert W, Mäder K. Solid lipid nanoparticles: production and applications. Adv Drug Deliv Rev. 2001;47(2-3):165–96.
28. Nataraja BT, Dharmalingam S, Keservani RK, Gupta AK, Pulipati S, Bhor RJ, Singh AK, Singh SK, Boddeda B. Silver nanoparticle formulation development and

evaluation: In-vitro anti-microbial evidences. JCHR. 2023;13(3):1389-96.
29. Shah RM, Malherbe F, Eldridge D, Palombo EA, Harding IH. Physicochemical characterization of solid lipid nanoparticles. J Colloid Interface Sci. 2014;428:286–94.
30. Patel NR, Damann K, Leonardi C, Sabliov CM. Amphotericin B nanoparticles. J Pharm Sci. 2010;99(5):2439–49.
31. Chono S, Tanino T, Seki T, Morimoto K. Efficient drug delivery to lungs. J Pharm Sci. 2008;97(6):2073–85.
32. Ahire ED, Surana KR, Keservani RK, Gupta AK, Yadav A, Bharti SK, Jaiswal M, Singh BK. Current overview of the nutraceutical nanoparticulate delivery technology with special emphasis on herbal formulation.
33. Laniado-Laborín R, Cabrales-Vargas MN. Amphotericin B: side effects. Rev Iberoam Micol. 2009;26(4):223–7.
34. Sawaya BP, Briggs JP, Schnermann J. Amphotericin B nephrotoxicity. J Am Soc Nephrol. 1995;6(2):154–64.
35. Ellis D. Amphotericin
36. B: spectrum and resistance. J Antimicrob Chemother. 2002;49(Suppl 1):7–10.