Proceedings of ICBioMed 2025 Symposium: AI for Healthcare: Advanced Medical Data Analytics and Smart Rehabilitation
DOI: 10.54254/2753-8818/2025.AU25804

Nanoparticles in Delivery Across the Blood-Brain Barrier

Jiangyuan Liu

School of Life Science, Xiamen University, Xiamen, China
36720222203967@stu.xmu.edu.cn

Abstract. The blood-brain barrier (BBB) is a critical physiological structure that limits the delivery of therapeutic agents to the central nervous system (CNS), posing a major challenge in the treatment of neurological diseases. Lipid nanoparticles (LNPs) have emerged as effective drug carriers due to their high biocompatibility, efficient encapsulation, and ability to facilitate intracellular delivery. Current research has explored multiple strategies to transport LNPs across the BBB, including direct intracerebral injection, receptor-mediated transcytosis (RMT), adsorptive-mediated transcytosis (AMT), and transporter-mediated transcytosis (TMT). These methods have demonstrated varying degrees of success in preclinical studies, with improvements in targeting efficiency, tissue distribution, and gene expression. Despite these advances, a comprehensive comparative understanding of the strengths and limitations of each delivery route remains insufficient, particularly regarding clinical translation and safety. This review analyzes four major LNP-based delivery approaches across the BBB, focusing on their mechanisms, representative applications, and practical limitations. Direct injection offers precise delivery but is invasive and limited in distribution. RMT provides high specificity but is affected by receptor expression variability. AMT and TMT offer receptor-independent or nutrient-mimicking routes but may cause off-target effects or disrupt normal transport processes.

Keywords: Lipid Nanoparticles, Blood-Brain Barrier, Central Nervous System.

1. Introduction

Lipid nanoparticles (LNPs) are excellent carriers for delivering small molecule drugs, especially mRNA drugs. Drugs using LNPs as carriers have become an emerging therapeutic method for treating various diseases. To be more specific, LNPs are being used as carriers to produce mRNA vaccines, treat cancer, and treat other genetic diseases. It is worth noting that LNPs based nanomedicine is being explored for the treatment of central nervous system (CNS) diseases such as Alzheimer's disease (AD), Parkinson's disease and glioma [1-3]. However, drugs are difficult to pass through the blood-brain barrier (BBB), which becomes a major obstacle to drug delivery. LNPs have better drug protection, higher encapsulation efficiency, better intracellular drug release performance, and higher safety, making them excellent candidates for CNS drug delivery.

In recent years, many researchers have explored various methods for transporting LNPs to the brain. The delivery of substances across the BBB can be divided into two categories: direct injection into the brain and mediated transcytosis. Mediated transcytosis can also be divided into receptor-

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-8818/2025.AU25804

mediated transcytosis (RMT), adsorptive-mediated transcytosis (AMT), and transporter-mediated transcytosis (TMT). This review will summarize the transportation principles through BBB, provide a detailed introduction to these delivery methods and their applications, and finally summarize their advantages and disadvantages.

2. Blood-brain barrier

BBB, as the most significant barrier to regulate the molecular exchange between blood and the brain, consists of endothelial cells, astrocytes, pericytes, microglia and other components, and selectively controls transportation of diverse molecules. Small molecule drugs can cross the BBB due to their lipophilicity and small molecular weight properties, while large molecules cannot directly cross the BBB. However, these macromolecules can target and bind to brain capillary endothelial cells (BCECs), which provides us with a way to break through the BBB through transcytosis. The function of BCECs is to selectively exchange substances in the bloodstream and CNS, protecting the brain from harmful substances. Only small molecules with lipid solubility and molecular weight less than 400-500Da can pass through the BBB. The permeation or transmembrane diffusion of these small molecules increases the risk of systemic side effects.

In general, BBB has high selectivity. White blood cells generally cannot enter the brain for protection. However, if inflammation occurs, the permeability of the BBB will change, allowing white blood cells to pass through the BBB. Some inflammatory signals, such as interleukins and cytokines, can create gaps or looseness between brain endothelial cells, promoting the passage of white blood cells through the BBB. There are also cases where white blood cells produce transient pores on the endothelial cell membrane. Simulating the delivery of white blood cells is a research approach for delivering drugs across the BBB.

In addition to simulating the pathway of white blood cells, both transporters and receptors can simulate the transcytosis across the BBB barrier, which will be described in detail later.

3. Bypass BBB via injection

Injection is an effective method of delivering substances to the brain, which can be divided into intrathecal injection and intracerebral injection. Before the LNPs, Karikó K et al validated the feasibility of injecting lipid nanoparticle mRNA complexes into the brain in 2001 [4]. The team used luciferase encoding mRNA to deliver to the rat brain and detected the expression of luciferase. Ultimately, it was found that luciferase could be expressed in the rat brain, confirming the feasibility of injecting this method. And the team also found that the expression level mediated by lipofectin complex was higher than that of naked mRNA. Lipofectin is a complex of the cationic lipid, N-(2,3-bis(oleyloq)propyl)-N,N,N-trimethylammonium chloride (DOTMA) and dioleoylphosphatidyl ethanolamine (DOPE) [5]. LNPs have lower toxicity compared to the lipofectin complex, therefore, LNPs are promising delivery vehicles. Rungta et al. revealed that the use of siRNA in LNPs through intracranial injection can effectively target cells with almost no toxicity [6]. In this experiment, injection effectively knocked down the expression of neuronal genes. They also found that neurons rely on apolipoprotein E to accumulate LNPs. Tanaka et al. also demonstrated that LNPs can deliver mRNA encapsulated within them into various neuronal cells through injection [7]. Overall, these early studies have demonstrated the feasibility of injection and LNPs as carriers.

In recent years, research has focused more on specific types of cells that are affected, or has demonstrated that gene editing tools delivered by LNPs can successfully exert their effects in specific cells through injection, which is more applicable. Li et al. injected mRNA containing Cre

DOI: 10.54254/2753-8818/2025.AU25804

into brain cannulas of Ai 14 mice for 4 consecutive days and observed the expression of the target gene in specific regions of the hippocampus [8]. However, they found that the transfected cells were located in the restricted brain region, so they believe that the penetration of LNP-mRNA complex after injection is also limited. For this issue, Tuma et al. made improvements to LNPs and constructed LNPs containing DLin-MC 3-DMA (MC3), ultimately proving that these LNPs have a larger transfection range and efficiency [9]. Xue et al. developed a different type of LNPs called TD5 BLNPs. It demonstrates comparable safety to MC3 LNPs and outperforms MC3 LNPs in delivering mRNA to brain tissue [10].

Overall, injecting LNPs into brain tissue is a simple, feasible, and relatively safe method, but it has the disadvantage of affecting fewer tissues. Developing new LNPs can help solve this problem.

4. Mediated transcytosis

4.1. RMT

RMT is considered to be the fundamental mechanism by which the body transports important macromolecules such as nutrients, antibodies, and signaling proteins to the brain through the overexpression of specific receptors on the surface of endothelial cell lumens. The usual way to achieve RMT is to attach specific ligands to the surface of LNPs, allowing them to bind to specific receptors and effectively cross the BBB [11]. Because this method is similar to the Trojan horse in ancient Greek mythology, these LNPs are called Trojan horse liposomes (THL). The most common targeted receptors for endothelial cells are low-density lipoprotein related protein (LRP) receptor, transferrin receptor (TfR), insulin receptor (IR), lactoferrin receptor (LfR), glutathione (GSH) transporter, scavenger receptors class B type I leptin, et. (Lep).

In 2003, Pardridge, W.M. et al. concluded that the optimal Trojan horse for LNPs is the monoclonal antibody (MAb) that binds to certain surface epitopes on brain endothelial receptors, such as insulin receptor (INSR) or TfR [12]. This team believes that optimizing THL requires sufficient conjugation of MAb and LNPs, as well as sufficient encapsulation within LNPs [12]. They also took electron microscope photos of THL and found that MAb extended onto LNP via polyethylene glycol (PEG) [12]. As early as 2002, Zhang et al. attempted to use THL to treat CNS diseases. They conjugated an antibody, human insulin receptor monoclonal antibody (HIRMAb) to the surface of LNP to create THL, which was applied to human glioma cells. By using confocal microscopy to detect the distribution of 3h and 24h THL in cells, it was demonstrated that the cells were located in the nuclear compartment after uptake of THL. But there was a problem of PEG lipid detachment in their experiment [13]. One reason for using HIRMAb THLs for plasmid DNA delivery to the nucleus is that INSR usually translocates to the nuclear compartment within the cell, as demonstrated by recent research results [14]. Batista T.M. et al. found that insulin receptor (INSR) binds to specific gene promoters after entering the nucleus. This may be the reason why HIRMAb has higher gene expression in the brain after delivering THL compared to TfRMAb [15].

In terms of clinical disease treatment applications, Jiang D et al. attempted to treat mice with Niemann Pick C1 disease using THL targeting mouse TfR in 2007 [16]. Although it alleviated certain disease manifestations, it did not prolong the lifespan of mice [16]. A research in 2009 showed that the treatment of Parkinson's disease relying on THL delivery achieved good results [17]. The research on glioma therapy started earlier, with studies on THL delivery of siRNA for glioma treatment in 2002, which extended the survival time of diseased mice [18]. Bruun J et al. designed LNP targeting LRP-1 to deliver siRNA for the treatment of glioma [19]. Tang L et al. designed an LNP with dual functional peptide that can target gliomas across the BBB [20].

DOI: 10.54254/2753-8818/2025.AU25804

RMT, represented by Trojan horses, has the advantages of strong selectivity and being safe and non-toxic. An experiment on rats demonstrated that weekly injection of LNP did not show any toxicity or inflammatory effects [21]. However, in recent years, there has been limited clinical research on this technology, and its effectiveness has not been clinically validated.

4.2. AMT

AMT is a pathway for transporting target molecules to the brain. Unlike RMT, AMT does not require specific transport proteins. This process relies on the interaction of charges. The endothelial cell membrane of BBB is not only covered by heparan sulfate proteoglycans (HSPG), but also contains many carboxyl groups of sialoglycoproteins and sialoglycolipids, which results in one side of BBB carrying many negative charges. Therefore, by conjugating the surface of LNPs with cationic groups, LNPs can pass through BBB through electrostatic interactions. This process can be divided into three key steps: electrostatic action causes BBB cells to engulf and transport vesicles, which then pass through the BBB from the luminal side, and finally fuse with the membrane to release the transported contents into brain tissue.

This is a theoretically feasible approach, and there are also many positively charged molecules applied to AMT, such as lectin, cardiolipin, heparin, etc. Although molecules related to AMT have been applied in many nanoparticles, their application in LNPs is very limited. Currently, cardiolipin is a representative molecule used to modify LNPs for transport via AMT. This molecule carries a positive charge, which allows LNPs to adsorb onto the BBB. Bereczki E et al. attempted to use cardiolipin modified LNPs to treat AD, which had the effect of reducing the toxicity of amyloid beta (Aβ) peptide and improving the survival rate of model cells [22]. Therefore, they proposed that it is possible to treat AD in this way. However, the research results of Ordóñez Gutiérrez L et al. are different from the above results. Ordóñez Gutiérrez et al. intraperitoneally injected cardiolipin LNPs into model mice. However, their results showed a significant decrease in plasma Aβ levels, with only a slight decrease in Aβ levels in the brain [23]. This result seems to indicate that cardiolipin LNPs cannot reduce Aβ in the brain. However, Gobbi et al.'s experiment also showed that despite this, cardiolipin LNPs exhibited affinity for Aβ, which still contributes to the development of new imaging systems or drugs [24].

There are many studies on the penetration of BBB through AMT, but there are relatively few related to LNPs, so there is still room for development and research. Researchers may develop new LNPs by trying more different positively charged molecules. Moreover, AMT is not specific and cannot guarantee specific targeting of certain cells, so attempts can be made to combine AMT with other delivery methods.

4.3. TMT

Transporter-mediated transcytosis, also known as carrier-mediated transcytosis, is a strategy that use transporters to supply molecules from blood to CNS. It is reported that there are over 20 different transporters in the BBB. Therefore, TMT may be an important method for designing drug carriers that cross the BBB. Molecules such as glucose, peptides, and nucleotides are transported through the TMT method. In this process, transporters first identify the substrate. Then the substrate and transporters combine to form a complex, during which the transporters may undergo changes. Finally, transport is completed based on the substrate concentration difference on both sides of the membrane where the transporters are located. For the three substances mentioned above, there are typical transporters in the BBB, namely glucose transporter 1 (GLUT1), GSH transporter, and amino

DOI: 10.54254/2753-8818/2025.AU25804

acid transporter. In addition, commonly used transporters include choke transporters, monocarboxylic acid transporters, amine transporters, etc. The expression of transporters on the BBB membrane is also astonishing, with transporters expressed 10-100 times more on the BBB membrane compared to other brain tissues [25].

There are 14 types of GLUTs in humans, and GLUT1 is one of them. GLUT1 is overexpressed in the BBB, thus it can mediate the passage of sugars. Some studies have shown that GLUT1 appears to be overexpressed in brain tumors, making it a candidate target for glioma treatment. At present, there have been relevant advances in this research. Singh et al. used a ligand derived from mannose, p-aminophenyl-α-D-mannopyranoside (MAN), to modify LNPs in order to obtain the ability to pass through the BBB [26]. They successfully delivered chemotherapy drug docetaxel (DTX) to the brain using MAN modified LNPs [26]. Pharmacokinetic analysis indicates an increased distribution of DTX in the brain [26].

GSH is a hydrophilic endogenous tripeptide. The principle of its involvement in TMT is to interact with the ATP binding cassette (ABC) transporter family on BBB cells. In 2014, Rip J et al. used GSH-PEG modified liposomes to deliver drugs to the mouse brain [27]. Their results indicate that the concentration of fluorescent tracer delivered using this LNPs is four times higher than that delivered by the control group [27]. Two years later, the research team made further progress and found that the increased distribution of ribavirin in the extracellular fluid of brain cells was related to the binding degree of GSH and LNPs [28]. These researches provide foundation for further developing LNPs based on the TMT principle for GSH.

For amino acids, there are also related transporters being studied. L-type amino acid transporter 1 (LAT1) is overexpressed in various cancer cells, including brain tumors, and is responsible for transporting neutral amino acids. Due to the highly expressed nature of LAT1 in brain cancer and BBB, it can be attempted to be used as a target for mediating BBB channels. In 2013, Kharya et al. used phenylalanine to target LAT1. Linking phenylalanine to solid LNPs enhances the uptake of LNPs by C6 glioma cells [29]. In addition, the team also demonstrated that PEG present on the surface of LNPs enhances the uptake of LNPs by C6 cells [29]. Through this method, a large amount of drugs are transported to the brain, demonstrating targeted potential [29]. Li L. et al. used different molecules to improve LNPs targeting LAT1 [30]. The team modified LNPs targeting LAT1 with Glu TPGs and found that the modified LNPs had stronger ability to penetrate the BBB and lower cytotoxicity [30].

As a delivery method, TMT has a wide range of target options and still has a lot of room for development. However, using this method may interfere with normal substance transport and has cytotoxicity.

5. Conclusion

This review summarized current strategies for delivering LNPs across the BBB, with a focus on four major approaches: direct injection, RMT, AMT, and TMT. Each method has distinct advantages and limitations in terms of targeting specificity, delivery efficiency, and clinical feasibility. LNPs, with their strong biocompatibility, high encapsulation efficiency, and ability to protect and deliver cargo across biological barriers, have emerged as promising vehicles for CNS therapies.

The analysis shows that while direct injection allows precise and effective delivery of mRNA and other agents, its invasiveness and limited diffusion remain challenges. RMT offers high selectivity via receptor targeting and has shown encouraging preclinical results in neurodegenerative and tumor models. However, clinical translation is hampered by receptor availability and species-specific differences. AMT enables receptor-independent delivery using cationic modifications but suffers

DOI: 10.54254/2753-8818/2025.AU25804

from low targeting specificity. TMT leverages natural transporters like GLUT1 and LAT1 for drug delivery but faces issues such as competition with endogenous substrates and potential toxicity.

Future research should explore hybrid delivery systems that integrate the strengths of different transcytosis pathways, as well as biomimetic designs that imitate leukocytes or exosomes. Advances in high-throughput screening, disease-specific BBB profiling, and synthetic ligand development may also yield more precise and effective delivery platforms.

References

[1] Luo, M., L. K. C. Lee, B. Peng, C. H. J. Choi, W. Y. Tong, and N. H. Voelcker. Delivering the Promise of Gene Therapy with Nanomedicines in Treating Central Nervous System Diseases. Advanced Science, vol. 9, no. 26, 2022, article e2201740.

[2] Jagaran, K., and M. Singh. Lipid Nanoparticles: Promising Treatment Approach for Parkinson's Disease. International Journal of Molecular Sciences, vol. 23, no. 16, 2022, article 9361.

[3] Luiz, M. T., L. B. Tofani, V. H. S. Araújo, L. D. Di Filippo, J. L. Duarte, J. M. Marchetti, and M. Chorilli. Gene Therapy Based on Lipid Nanoparticles as Non-Viral Vectors for Glioma Treatment. Current Gene Therapy, vol. 21, no. 5, 2021, pp. 452–463.

[4] Karikó, K., J. M. Keller, V. A. Harris, D. J. Langer, and F. A. Welsh. In Vivo Protein Expression from mRNA Delivered into Adult Rat Brain. Journal of Neuroscience Methods, vol. 105, no. 1, 2001, pp. 77–86.

[5] Mahato, R. I., K. Kawabata, T. Nomura, Y. Takakura, and M. Hashida. Physicochemical and Pharmacokinetic Characteristics of Plasmid DNA/Cationic Liposome Complexes. Journal of Pharmaceutical Sciences, vol. 84, no. 11, 1995, pp. 1267–1271.

[6] Rungta, R. L., H. B. Choi, P. J. Lin, R. W. Ko, D. Ashby, J. Nair, M. Manoharan, P. R. Cullis, and B. A. Macvicar. Lipid Nanoparticle Delivery of siRNA to Silence Neuronal Gene Expression in the Brain. Molecular Therapy – Nucleic Acids, vol. 2, no. 12, 2013, article e136.

[7] Tanaka, H., T. Nakatani, T. Furihata, K. Tange, Y. Nakai, H. Yoshioka, H. Harashima, and H. Akita. In Vivo Introduction of mRNA Encapsulated in Lipid Nanoparticles to Brain Neuronal Cells and Astrocytes via Intracerebroventricular Administration. Molecular Pharmaceutics, vol. 15, no. 5, 2018, pp. 2060–2067.

[8] Li, Y., R. Jarvis, K. Zhu, Z. Glass, R. Ogurlu, P. Gao, P. Li, J. Chen, Y. Yu, Y. Yang, and Q. Xu. Protein and mRNA Delivery Enabled by Cholesteryl-Based Biodegradable Lipidoid Nanoparticles. Angewandte Chemie International Edition, vol. 59, no. 35, 2020, pp. 14957–14964.

[9] Tuma, J., Y. J. Chen, M. G. Collins, A. Paul, J. Li, H. Han, R. Sharma, N. Murthy, and H. Y. Lee. Lipid Nanoparticles Deliver mRNA to the Brain after an Intracerebral Injection. Biochemistry, vol. 62, no. 24, 2023, pp. 3533–3547.

[10] Xue, Y., C. Wang, H. Li, S. Du, Y. Zhong, Y. Zhang, S. Wang, K. Guo, X. Hou, D. D. Kang, Z. Liu, M. Tian, D. Cao, B. Deng, D. W. McComb, T. Markovic, J. Pan, M. Borna, E. J. Nestler, P. C. Peng, and Y. Dong. Lipid Nanoparticles Enhance mRNA Delivery to the Central Nervous System Upon Intrathecal Injection. Advanced Materials, vol. 37, no. 27, 2025, article e2417097.

[11] Pardridge, W. M. A Historical Review of Brain Drug Delivery. Pharmaceutics, vol. 14, no. 6, 2022, article 1283.

[12] Pardridge, W. M. Gene Targeting in Vivo with Pegylated Immunoliposomes. Methods in Enzymology, vol. 373, 2003, pp. 507–528.

[13] Zhang, Y., H. Jeong Lee, R. J. Boado, and W. M. Pardridge. Receptor-Mediated Delivery of an Antisense Gene to Human Brain Cancer Cells. Journal of Gene Medicine, vol. 4, no. 2, 2002, pp. 183–194.

[14] Amaya, M. J., A. G. Oliveira, E. S. Guimarães, M. C. Casteluber, S. M. Carvalho, L. M. Andrade, M. C. Pinto, A. Mennone, C. A. Oliveira, R. R. Resende, G. B. Menezes, M. H. Nathanson, and M. F. Leite. The Insulin Receptor Translocates to the Nucleus to Regulate Cell Proliferation in Liver. Hepatology, vol. 59, no. 1, 2014, pp. 274–283.

[15] Batista, T. M., C. T. Cederquist, and C. R. Kahn. The Insulin Receptor Goes Nuclear. Cell Research, vol. 29, no. 7, 2019, pp. 509–511.

[16] Jiang, D., H. Lee, and W. M. Pardridge. Plasmid DNA Gene Therapy of the Niemann-Pick C1 Mouse with Transferrin Receptor-Targeted Trojan Horse Liposomes. Scientific Reports, vol. 10, no. 1, 2020, article 13334.

[17] Zhang, Y., and W. M. Pardridge. Near Complete Rescue of Experimental Parkinson's Disease with Intravenous, Non-Viral GDNF Gene Therapy. Pharmaceutical Research, vol. 26, no. 5, 2009, pp. 1059–1063.

[18] Zhang, Y., C. Zhu, and W. M. Pardridge. Antisense Gene Therapy of Brain Cancer with an Artificial Virus Gene Delivery System. Molecular Therapy, vol. 6, no. 1, 2002, pp. 67–72.

DOI: 10.54254/2753-8818/2025.AU25804

[19] Bruun, J., T. B. Larsen, R. I. Jølck, R. Eliasen, R. Holm, T. Gjetting, and T. L. Andresen. Investigation of Enzyme-Sensitive Lipid Nanoparticles for Delivery of siRNA to Blood-Brain Barrier and Glioma Cells. International Journal of Nanomedicine, vol. 10, 2015, pp. 5995–6008.
[20] Tang, L., R. Zhang, Y. Wang, M. Liu, D. Hu, Y. Wang, and L. Yang. A Blood-Brain Barrier- and Blood-Brain Tumor Barrier-Penetrating siRNA Delivery System Targeting Gliomas for Brain Tumor Immunotherapy. Journal of Controlled Release, vol. 369, 2024, pp. 642–657.
[21] Zhang, Y. F., R. J. Boado, and W. M. Pardridge. Absence of Toxicity of Chronic Weekly Intravenous Gene Therapy with Pegylated Immunoliposomes. Pharmaceutical Research, vol. 20, no. 11, 2003, pp. 1779–1785.
[22] Bereczki, E., R. Re, M. E. Masserini, B. Winblad, and J. J. Pei. Liposomes Functionalized with Acidic Lipids Rescue Aβ-Induced Toxicity in Murine Neuroblastoma Cells. Nanomedicine, vol. 7, no. 5, 2011, pp. 560–571.
[23] Ordóñez-Gutiérrez, L., R. Re, E. Bereczki, E. Ioja, M. Gregori, A. J. Andersen, M. Antón, S. M. Moghimi, J. J. Pei, M. Masserini, and F. Wandosell. Repeated Intraperitoneal Injections of Liposomes Containing Phosphatidic Acid and Cardiolipin Reduce Amyloid-β Levels in APP/PS1 Transgenic Mice. Nanomedicine, vol. 11, no. 2, 2015, pp. 421–430.
[24] Gobbi, M., R. Re, M. Canovi, M. Beeg, M. Gregori, S. Sesana, S. Sonnino, D. Brogioli, C. Musicanti, P. Gasco, M. Salmona, and M. E. Masserini. Lipid-Based Nanoparticles with High Binding Affinity for Amyloid-Beta1-42 Peptide. Biomaterials, vol. 31, no. 25, 2010, pp. 6519–6529.
[25] Smith, Q. R. International Congress Series. Elsevier, USA, 2005, p. 63.
[26] Singh, I., R. Swami, M. K. Jeengar, W. Khan, R. Sistla. p-Aminophenyl-α-D-Mannopyranoside Engineered Lipidic Nanoparticles for Effective Delivery of Docetaxel to Brain. Chemistry and Physics of Lipids, vol. 188, 2015, pp. 1–9.
[27] Rip, J., L. Chen, R. Hartman, A. van den Heuvel, A. Reijerkerk, J. van Kregten, B. van der Boom, C. Appeldoorn, M. de Boer, D. Maussang, E. C. de Lange, and P. J. Gaillard. Glutathione PEGylated Liposomes: Pharmacokinetics and Delivery of Cargo across the Blood-Brain Barrier in Rats. Journal of Drug Targeting, vol. 22, no. 5, 2014, pp. 460–467.
[28] Maussang, D., J. Rip, J. van Kregten, A. van den Heuvel, S. van der Pol, B. van der Boom, A. Reijerkerk, L. Chen, M. de Boer, P. Gaillard, H. de Vries. Glutathione Conjugation Dose-Dependently Increases Brain-Specific Liposomal Drug Delivery In Vitro and In Vivo. Drug Discovery Today: Technologies, vol. 20, 2016, pp. 59–69.
[29] Kharya, P., A. Jain, A. Gulbake, S. Shilpi, A. Jain, P. Hurkat, S. Majumdar, and S. K. Jain. Phenylalanine-Coupled Solid Lipid Nanoparticles for Brain Tumor Targeting. Journal of Nanoparticle Research, vol. 15, 2013, pp. 1–12.
[30] Li, L., X. Di, S. Zhang, Q. Kan, H. Liu, T. Lu, Y. Wang, Q. Fu, J. Sun, and Z. He. Large Amino Acid Transporter 1 Mediated Glutamate Modified Docetaxel-Loaded Liposomes for Glioma Targeting. Colloids and Surfaces B: Biointerfaces, vol. 141, 2016, pp. 260–267.