Application of Liposomes in Pulmonary Drug Delivery and Respiratory Disease Treatment

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Abstract. With environmental problems becoming more and more serious, the incidence rate of respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD) and lung infection continues to rise, posing a serious threat to human health. Traditional drugs have the limitations of poor targeting, short duration of efficacy and difficult to control drug release. However, novel nanomedicines can make up for these shortcomings, improve drug efficacy and accelerate patient recovery. This article will explore the application mechanism and clinical value of lipid carriers in the treatment of lung diseases, with a focus on analyzing the unique advantages of solid lipid nanoparticles (SLNs), liposomes, and other carriers for drug delivery. Research has shown that lipid carriers can significantly enhance the ability of drugs to penetrate the mucosal barrier by regulating particle size and surface modification, and PEG-modified nanoparticles exhibit excellent mucosal permeability and cellular uptake efficiency in asthma models. In addition, drug-loaded SLN can reduce cell infiltration in COPD model mice with bronchitis (inflammation factor levels decreased by 42%), and improve alveolar epithelial hyperplasia and excessive mucus secretion]. Finally, lipid carriers prolong drug action time through their sustained release properties, and their biocompatibility can reduce the risk of immune rejection. This study can not only provide efficient treatment plans for lung diseases but also reduce drug risks, greatly improving the efficiency of lung disease treatment.

Keywords: Lipid-based carriers, Targeted drug delivery, Respiratory diseases.

1. Introduction

With the development of society, respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), lung cancer, and lung infections caused by automobile exhaust, environmental pollution, smoking, and dust are becoming increasingly prevalent, seriously jeopardizing people's health and potentially contributing to the risk of death. Tuberculosis (TB) is a chronic infectious disease caused by Mycobacterium tuberculosis complex, which is highly contagious and is characterized by symptoms such as chest pain, cough and fever. People can become infected by spreading small viral particles through sneezing and coughing. However, many common drugs have certain toxicity and significant obstacles in transportation, in contrast to nanodelivery systems that can significantly enhance the targeting of drug delivery. Compared with traditional delivery methods, several nanoparticle delivery strategies have been used to improve detection methods and drug treatment efficacy. Delivering nanoparticles to the lungs, loading appropriate therapeutic drugs, and combining intelligent functions to overcome various pulmonary obstacles. Asthma is a chronic disease characterized by airway inflammation and increased airway hyperresponsiveness, leading to symptoms such as difficulty breathing, coughing, and chest tightness. Hundreds of millions of people worldwide suffer from asthma, which has a serious impact on their quality of life and health.

A significant feature of asthma is the reversibility of airway stenosis. The airways of the human lungs, also known as bronchi, are essentially tubular structures with muscular walls. On the surface of the inner layer cells of the bronchi, there is an extremely small ultrastructure called receptors. When these receptors interact with specific substances, they trigger a series of physiological reactions that stimulate the muscles below them to produce contraction or relaxation movements, and this muscle activity ultimately leads to changes in airway diameter, thereby altering the airflow conditions

[1]. The advancement of new nanotechnology treatment methods to address asthma issues, can effectively improve drug efficacy and targeting. Researchers have delved into using a variety of nanomaterials and micromaterials for asthma treatment. These include polymeric nanoparticles, which have shown potential due to their unique chemical properties; solid lipid nanoparticles, which are valued for their biocompatibility; extracellular vesicle nanomaterials, which play an interesting role in cellular communication; and metallic nanoparticles, known for their distinct physical characteristics [1]

2. Classification of Lipid Carriers

Liposomes are microvesicles with a bilayer structure formed by dispersing phospholipids and other lipids in water. Their advantages in terms of size, hydrophobicity and hydrophilicity make them good drugs for the treatment of lung diseases. Liposomes can spontaneously form bilayer lipid vesicles to encapsulate water-soluble drugs, and various associated enzymes and substances inside can dissolve water-soluble drugs [2]. Structurally, liposomes are spherical or multilayered spherical containers made of diacyl chain phospholipids (lipid bilayers) self-assembled in an aqueous solution. The bilayer phospholipid membrane has a hydrophobic tail and a hydrophilic head, leading to the formation of an amphiphilic structure [3]. Liposomes have a large number of lipid molecules on the surface that can easily fuse with lipophilic cell membranes, allowing free diffusion of the drug into the cell. When liposomes are used for drug delivery, the required vesicles usually extend from 50 nm to 150 nm, showing excellent adaptability.

3. Nano-structured Lipid Carriers (NLCs）

The size in the nanometer range makes it easy for NLCs to enter cells through endocytosis, and drugs are lipophilic small molecules. They can diffuse freely through the cell membrane mediated by lipids, delivering water-soluble drugs through body fluids to various locations. They encapsulate easily decomposable drugs, preventing them from being destroyed in the body and allowing them to function better. NLCs improve the oral absorption rate of drugs, efficiently regulate the release rate of drugs, and release drugs based on the characteristics of the patient's lungs. The special coating makes the carrier more stable and better able to enter the body. NLCs are broken down by some systems in the body after entering the bloodstream, including hydrophilic polymers such as polyoxyethylene ether and polyethylene glycol (PEG), which wrap around their surface and increase the time NLCs exist in the bloodstream [3]. Secondly, nano lipid carriers can achieve precise drug delivery and have active targeting properties [3-5]. The proteins and ligands on its surface can bind to specific receptors with specificity, significantly improving the therapeutic effect while reducing the side effects caused by drugs.

4. Solid lipid nanoparticles (SLN)

SLN has attracted increasing attention as a delivery system for hydrophobic drugs. They are prepared from systems for hydrophobic drugs. They are prepared from lipids and can be administered through different routes of drug delivery such as oral, injectable, dermal, transdermal, ocular and pulmonary [6]. In addition, SLNs also have numerous advantages that make, them a good carrier for drug delivery. Firstly, it can precisely regulate drug release and targeted delivery. After the drug is encapsulated by changing the composition of lipids, the release rate of the drug can be adjusted to achieve sustained and slow release, thereby prolonging the drug's duration of action [5]. Secondly, it can significantly enhance drug stability. Drugs often face stability challenges in storage and in vivo environments, and SLNs provide stable protection for drugs. The degradation and inactivation of circumvent drugs ensure their efficacy and sustainability. Thirdly, it has a high drug-loading attribute due to its unique structure and composition. Compared with other nanocarriers, SLNs can load more

drugs, which means that at the same dosage, more effective drug components can be delivered to the target site, improving treatment efficacy and reducing treatment frequency. Finally, as drug carriers, SLNs have minimal toxicity. Its main components are natural or synthetic lipids, which have good biocompatibility, are not prone to immune reactions and toxic side effects, and improve the safety of drugs.

Lipid carriers have many properties suitable for use as lung nanoparticle carriers, such as structural similarity to human biofilms. One of the main drawbacks of most formulations is their inability to confer cell specificity [6]. A lipid carrier called SLN became a drug that can be used for systemic delivery because it binds well to the DNA in the cells and this property helps the carrier not to activate macrophages and other immune systems and therefore it has less toxins. This toxin is caused by the immune system response in the body and passes easily through the cell membrane [6].

Nano lipid carriers (NLBC) are superior to conventional targeted therapy delivery due to their better biocompatibility, intrinsic permeability, ease of manufacture and non-toxicity [7]. Another property is the controlled drug release characteristics, which can be controlled by the structure of the lipid carrier (e.g., pH or temperature). Under specific conditions, the drug is released in vivo. For some diseases that require hydrophobic and hydrophilic drugs, nanolipid carriers can be controlled for better properties to transport the drug. Different and wide range of compounds can be filled into the carriers, which brings a great prospect for drug application [8]. For some drugs with low solubility, lipid carriers can enhance the absorption and use of drugs by increasing their solubility in water. Carriers are also highly sustainable and can protect drugs from environmental oxidation and erosion, prolonging their lifespan. For example, nanolipid carriers can be used using the liquid method, which is an effective method for encapsulating hydrophilic active drugs in lipid carriers. In this method, the hydrophilic drug is dissolved in an aqueous solution and mixed with the lipid substance [9]. The single emulsion is more sustainable and can be used for lung recovery.

5. Application in the Treatment of Asthma

Asthma is one of the most common chronic lung diseases. The traditional method relies on Corticosteroids. Inhalation of corticosteroids does not pharmacokinetics well in the lungs and the effects are short-lasting because the medicine would be absorbed by the whole body by the blood and most of the medicine in the lungs would be released. The treatment of asthma can show the advantage of the nanolipid carrier. In the medicine delivery process, Lipid carriers containing bronchodilators or anti-inflammatory drugs are precisely delivered to airway smooth muscle cells or inflammatory cells through the pulmonary inhalation route to exert mechanisms of airway dilation and anti-inflammatory effects. FcBP is a special medicine to overcome the problem of the nanoparticle, The mucus layer covering the airway and ciliated epithelium restrain the medicine delivery. They use PEG to Promote the penetration of mucus [10]. FcBP functionalization does not affect the mucus permeability of PEG-NP and promotes cellular uptake by specific interaction with FcRn [10]. For the testing, the nanolipid medicine shows better properties like the index of the lung function, and the decrease of the opposite responses. Like in the COPD animal model test of mice. In the discovery of the Effect of Flower-shaped Lactose-loaded Curcumin Solid Lipid Nanoparticles Inhalation Micropowder on Pulmonary Inflammation in COPD Model Mice [4]. In the study, COPD model mice were replicated by intratracheal instillation of porcine trypsin, total white blood cell count, neutrophil count, and eosinophil count in the model mice increased significantly. Cur-SLN-FL also brings a similar reflection, which means the nano lipid carrier can be used to decrease the accumulation of inflammatory cells in the bronchi and reduce lung inflammation, after the high dose of the Cur-SLN-FL The hyperplasia and thickening of the ciliated columnar epithelium in the mouse trachea, as well as the shedding condition, have improved, with occasional mucus accumulation observed within the lumen. There is mild inflammatory cell infiltration in the lung tissue interstitium [11]. The nanolipid carrier would not cause Pulmonary irritation, but the test does not show the result in the long term. The sustainability also needs to be tested.

6. Specific Cases in the Treatment of Lung Infections

Acknowledgements In optimization and trans follicular delivery of finasteride-loaded protosomes in hair growth stimulation in C57BL/6Mlac mice. In the COPD test,50 big mice use normal medicine and the normal medicine covered by the nanolipid carrier separately for 8 weeks. Mice using nanolipid carrier medicine show the lung cells with inflammation are decreased significantly. The levels of inflammatory cytokines TNF-α and IL-6 decreased by 40% and 35%, respectively, and the degree of pulmonary fibrosis decreased. However, the level of inflammatory factors in the common drug group decreased by only 20% and 15%, and the improvement of pulmonary fibrosis was not obvious [12].

The nanolipid carrier medicine shows a markable advancement, the medical system should consider the antimicrobials nanolipid medicine method to cure the lung disease caused by germs. Pharmaceutical companies should conduct in-depth research on the lipid carrier adaptability of different antimicrobial drugs to expand the scope of application. Compared to other medicines to cure lung germs. Nanolipid medicine can enhance the Antibacterial effect, shorten the treatment cycle, and reduce adverse reactions. However, medicine production still needs a large cost, the material and nano lipid use need to be enhanced in the future, and the durability problem also needs to be considered. Medical companies should concentrate on these problems and solve them in the future, to show the advantages of nanolipid carrier medicine. For fungal infections of the lungs, Efficacy and safety of liposomal Ciprofloxacin in adults with chronic Pseudomonas aeruginosa pulmonary infections caused by Ciprofloxacin strains and CFNCFB, it is demonstrated that once daily inhalation dose has a strong anti-pseudomonas microbiological efficacy and is well tolerated [11]. Pulmaquin™ which uses the nanolipid carrier enlarges the time of primary time of the worson of the lungs. Lipid carriers have obvious advantages in the treatment of pulmonary infections. It is recommended that medical institutions give preference to antimicrobial drugs in the form of lipid carriers for the treatment of pulmonary infections. It has a higher rate of decrease of the germs elimination and shorten the time use.

7. Conclusion

As respiratory diseases become increasingly prevalent, nanocarrier with unique advantages of curing Asthma and lung infections shows better results, it can deliver the medicine precisely and enhance the effect of the medicine with fewer side effects, but there are problems such as high cost and durability to be improved. Lipid carriers, such as liposomes, nanostructured lipid carriers (NLCs) and solid lipid nanoparticles (SLN)have good biocompatibility, drug delivery and controlled release capabilities due to their similar structures to human biofilms. Lipid carriers, such as liposomes, nanostructured lipid carriers (NLCs) and solid lipid nanoparticles (SLN), have good Biocompatibility, drug delivery and controlled release capabilities due to their similar structures to human biofilms. For pulmonary infection, nano-lipid carrier drugs can significantly reduce the number of inflammatory cells and inflammatory factors, reduce pulmonary fibrosis, enhance the antibacterial effect, shorten the treatment cycle, and reduce adverse reactions. The creation and development of new aspects of nanomaterial give a better way to cure the disease It is helpful to improve the treatment effect of lung diseases and promote the development of the medical field. However, there are some problems in nano-lipid carriers, such as high production cost, optimization of materials and use, and durability to be studied, future research should focus on these aspects. In the research, there are a lot of limitations, and the durable problems are hard to test in the present experiment, whether it can play a stable role in a longer period of time and maintain the sustainability of drug efficacy is not clear. In the treatment of asthma and pulmonary infection, nano-lipid carrier drugs mostly lack long-term effect verification, and their long-term safety and effectiveness need to be further investigated. In the future, Pharmaceutical Enterprises will further study the compatibility of different antibacterial drugs with lipid carriers, exploring the feasibility of carrying more drugs on nano lipid carriers, so as to expand the application scope of nano lipid carrier drugs, and improve the efficiency of drug delivery, to

provide a new option for the treatment of more lung diseases. Scientific researchers need to focus on developing new preparation processes and materials. There are more properties that need to be tested, like stability and durability, while reducing production costs, and improve the stability, durability, and drug-loading capacity of nano-lipid carriers to enhance their overall performance. To conduct more large-scale, long-term clinical trials to comprehensively evaluate the safety and efficacy of nanolipocarrier drugs in humans is also a significant need to be started.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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