Shweta Yadav. et al. / Asian Journal of Research in Biological and Pharmaceutical Sciences. 11(3), 2023, 69-79.

Review Article **ISSN: 2349 – 4492**

Asian Journal of Research in Biological and Pharmaceutical Sciences

Journal home page: www.ajrbps.com

https://doi.org/10.36673/AJRBPS.2023.v11.i03.A08

NASOPULMONARY MEDICATION DELIVERY SYSTEMS: A REVIEW

Shweta Yadav*[1], Pragya Mishra[1], Shashi Kant Singh[2], Navneet Kumar Verma[1], Uma Srivastava[3], Ankur Srivastava[4]

[1*]Buddha Institute of Pharmacy, Gida, Gorakhpur, Uttar Pradesh, India.
[2]Faculty of Pharmaceutical Sciences, Mahayogi University, Gorakhpur, Uttar Pradesh, India.
[3]Department of Mathematics and Statistics, DDU Gorakhpur University, Gorakhpur, Uttar Pradesh, India.
[4]Institute of Pharmacy, Dr. Ram Manohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India.

ABSTRACT

The goal of this thorough review is to investigate the potential applications of nasopulmonary drug delivery devices for nasal drug administration in the future. Due to its many benefits, including as quick absorption, avoiding first-pass metabolism and non-invasive administration, nasal medication delivery has drawn a lot of attention. An introduction of nasal anatomy and physiology is given in this review, along with a discussion of the variables affecting drug absorption and bioavailability. It also goes over the several kinds of nasopulmonary medication delivery systems, including gels, powders, and sprays, and their benefits and drawbacks. The paper also explores the difficulties in nasal drug delivery, such as problems with mucociliary clearance, nasal discomfort, and formulation. There is also discussion of the possible uses of nasopulmonary drug delivery devices in the management of a number of illnesses, including allergies, respiratory issues and systemic problems. The analysis culminates with a future viewpoint on nasopulmonary drug delivery systems, highlighting the necessity for additional research and development to maximize their safety and efficacy.

KEYWORDS

Nasal pulmonary, Nasal route, Nasal delivery, Nasal spray, Nasal mucosa, Gels, Drops and Nasal approaches.

Author for Correspondence:

Shweta Yadav,
Buddha Institute of Pharmacy,
Gida, Gorakhpur, Uttar Pradesh, India.

Email: shwetay715@gmail.com

INTRODUCTION

The nasopulmonary drug delivery system has become a viable method for effective drug delivery via the nasal route in recent years. This thorough analysis seeks to investigate the prospective uses and advantages of this cutting-edge medication delivery technology in the future. Noninvasive techniques to transport medications through the nose and into the lungs are known as nasopulmonary drug delivery system or NPDDS for short. These systems have a number of benefits over conventional oral and injectable drug delivery techniques, such as quick absorption due to the nasal and pulmonary mucosa's large surface area and high vascularity, which allows drugs to enter the bloodstream quickly; avoidance of first-pass metabolism because drugs administered through the NPDDS avoid the liver, which prevents first-pass metabolism from occurring, which can lower the bioavailability of some drugs; targeted delivery since medications may be directed toward the lungs directly using the NPDDS, which is especially advantageous for the treatment of respiratory conditions; administration simplicity: Because NPDDS are very simple to use, patients who are unable or unwilling to take oral or injectable drugs may find them to be a helpful alternative[1,2].

Nebulizers, inhalers, and nasal sprays are commonly used to give NPDDS. The medication being given and the intended place of action determine the kind of device that is used. Several medications are commonly administered via NPDDS, including: asthma medications, which include leukotriene inhibitors, bronchodilators, and inhaled corticosteroids; nasal decongestants, which are nasal sprays that relieve nasal congestion caused by allergies or the common cold; migraine medications, which include Sumatriptan, which is an inhaled medication; and hormone replacement therapy, which involves the administration of estrogen and testosterone as nasal sprays[3-5].

ANATOMY AND PHYSIOLOGY OF NASAL DRUG DELIVERY SYSTEM

The nasal vestibule, which is the most anterior portion of the nasal cavity, opens to the face through the nostril. The nasal septum divides the nasal cavity in half and extends posteriorly to the nasopharynx. The nasal vestibule, olfactory area, and respiratory region are the three primary regions that make up the nose cavity. The lateral walls of the nasal cavity, which comprise a folded structure, can extend the surface area of the nose by around 150 cm; this is a very high surface area relative to its modest volume. The superior, median, and inferior turbinates make up this folded structure. The small channels that make up the main nasal airway, which are typically 1-3mm diameter, help the nose perform its primary activities. The mucosal membrane lining the nasal cavity is classified into two sections: the olfactory and non-olfactory epithelium.

The nasal vestibule, which has skin-like stratified squamous epithelial cells covering it, and the respiratory region, which has a typical airways epithelium coated in numerous microvilli, are examples of the non-olfactory area. These areas together provide a huge surface area that is available for drug absorption and delivery. This causes the mucus layer to be forced from the nasal cavity's anterior to its posterior region. The mucus membrane covering the nasal turbinate and the atrium contains goblet cells, which release mucus in the form of mucus granules that swell in the nasal fluid and add to the mucus layer. Adult nasal secretions should have a pH of 5.-6.5; infants and young children should have a pH of 5.0-6.7. Mucous membrane covers the nasal cavity. 95% water, 2% mucin, 1% salt, 1% additional proteins such albumin, lysozyme, and lactoferrin, and 1% lipids make up mucus production[6,7].

The Mechanism of Drug Delivery in Nasal Drug Delivery System

The nasal mucosa, a highly vascularized and permeable membrane lining the nasal cavity, must be crossed for medications to be absorbed by the nasal route. The nasal mucosa is an appealing delivery channel for drugs because it has a huge surface area and direct access to the bloodstream. The effective transfer of medications from the nasal cavity into the systemic circulation or to specific locations within the respiratory tract is facilitated by a number of crucial processes in the mechanism of drug administration in nasal drug delivery systems[8].

The drug formulation is usually sprayed or powdered into the nasal cavity during administration. The nasal mucosa, which has a high concentration of blood vessels and a significant surface area for drug absorption, is next in touch with the drug. The integrity of the nasal epithelium, the physicochemical features of the medicine, and its formulation all have an impact on how well it is absorbed in the nasal mucosa. Drugs can circumvent the liver's first pass metabolism once they are absorbed and enter the systemic circulation directly through the highly vascularized nasal mucosa. As an alternative, medications can go through the trigeminal or olfactory nerves to the central nervous system or other respiratory tract target areas.

In addition to facilitating targeted drug administration to particular areas of the lungs or nasal cavity, nasal drug delivery systems can help reduce systemic adverse effects while increasing therapeutic efficacy[9]. In order to affect medication bioavailability, pharmacokinetics, and therapeutic results, the mechanism of drug delivery in nasal drug delivery systems therefore entails a complex interaction of parameters affecting drug absorption, distribution and targeting within the nasal and pulmonary regions.

There are two basic methods that the drug's molecule can pass through the nasal mucosa:

Transcellular Pathway

This is the preferred route for lipophilic medicines, as they can dissolve in the lipid bilayer of cell membranes. They go straight through the nasal mucosa's lining epithelial cells.

Paracellular Pathway

This pathway is mainly used by hydrophilic medicines, which have difficulty passing through the cell membrane. They move through the voids left by the individual epithelial cells[10,11].

NASAL DRUG DELIVERY SYSYM'S ADVANTAGES[12]

Avoided first pass metabolism in the liver.

Quick onset of effect and rapid absorption of the medication.

By using an absorption enhancer, the bioavailability of bigger medication molecules can be increased.

Medications with low stability G.I.T. fluids administered via nasal route.

Simple and practical.

Simple to administer to people who are unconscious.

DISADVANTAGES[12]

Pathologic disorders like allergies or colds can drastically change how much bioavailability is in the nose.

It is currently unclear whether the absorption enhancers utilized in nasal drug delivery systems are histologically harmful.

Patients may experience some inconvenience as compared to oral delivery systems due to the potential for nasal discomfort.

The nasal cavity offers a reduced surface area for absorption in comparison to the gastrointestinal tract.

PULMONARY DRUG DELIVERY SYSTEM[13]

One of the earliest methods of drug administration is through the respiratory system. In recent years, inhalation treatment has proven to be an effective means of treating lung conditions locally, including asthma and chronic obstructive pulmonary disease, or COPD.

This kind of medication application in the treatment of various illnesses is obviously a targeted drug delivery method. The most widely sold goods are aerosol inhalation products with localized pulmonary effects.

The medication used to treat COPD and asthma, such as agonists like terbutalin formoterol and salbutamol (albuterol), corticosteroids like beclomethasone, flixotide, or budesonide, and mast cell stabilizers like sodium cromoglycate or nedrocromi.

The newest and most likely one of the most promising uses of pulmonary medication delivery is.

Its application to attain the medication compounds' systemic absorption after administration.

The respiratory tract may be a useful point of entry, especially for compounds such as proteins or peptides that have a low bioavailability when taken orally.

ANATOMY OF RESPIRATORY TRACT[14,15]

The respiratory system in humans is a complex organ system with closely related structure and function. Two regions made up the system:

The system that conducts

The area of the respiratory system

The nasal cavity and its accompanying sinuses, as well as the nasopharynx, oropharynx, larynx, trachea, bronchi, and bronchiales, further divide the airway.

Alveolar sacs, alveolar ducts, and respiratory bronchioles make up the respiratory regions.

From the mouth to the alveoli, the human respiratory tract is a branching system of air channels with about 23 bifurcations. Gas exchange, which involves supplying oxygen to and extracting carbon dioxide from blood as it passes through the pulmonary capillary bed, is the primary function of the lungs.

ADVANTAGES OF PULMONARY DRUG DELIVERY SYSTEM[16]

It is possible to lower the dosage required to have a pharmacological effect.

Systemic side-effects are linked to lower quantities in the systemic circulation.

Quick start of action.

Preventing stomach disturbances avoiding the metabolism.

First-pass Hepatic and Intestinal

DISADVANTAGES[16]

Low delivery efficiency and quantity of medication each puff.

Focusing on issues.

Poor medication formulation stability.

Issues with protein-based medication immunogenicity.

Phagocytosis and mucociliary elimination of drugs quickly.

MECHANISM OF PULMONARY DRUG DELIVERY SYSTEM[17]

There are numerous variables that influence the intricate process of inhaled particle deposition in the various parts of the respiratory system. The following are a few variables that affect respiratory deposition:

Lung volume

Respiration volume

Breathing rate

Mouth or nose breathing

Individual well-being

The hydrodynamic flow field is continuously changing as a result of airway bifurcations. One of the following main methods, depending on the respiratory system, airflow, and particle size, causes particle deposition: Particle deposition mechanism in airways:

Brownian diffusion, sedimentation and inertial impaction.

Factors Affecting Nasal Drug Absorption[18]

Drug Properties

A drug's capacity to pass through the nasal mucosa is influenced by its lipophilicity, molecular weight, and solubility.

Nasal Mucosa

Age, health and environmental factors can all affect the mucosa's thickness and permeability.

Formulation

Chemical absorption and nasal tolerability can be affected by the formulation's pH, viscosity, and osmolarity.

ADVANTAGES OF PULMONARY DRUG DELIVERY[19]

There is no need for a needle during pulmonary delivery

The small and fractional oral dose required

Reduced systemic side effects are linked to low concentration in the systemic circulation

Fast onset of action

Avoidance of gastrointestinal upset

Avoidance of drug degradation by liver in pulmonary drug delivery

Studies conducted thus far suggest that the nasal route is an alternative to parenteralroute, particularly for protein and peptide drugs

Convenient for patients, especially those on long-term therapy, when compared to parenteral medication

Drugs with poor stability in G.I.T. fluids are administered via the nasal route

Polar compounds exhibiting poor oral absorption may be especially well-suited for this form of delivery.

DISADVANTAGES OF PULMONARY DRUG DELIVERY[19]

Oropharyngeal deposition causes a side effect that is local.

The patient can find it challenging to correctly use the pulmonary medication devices.

The mucous layer may act as a physical barrier to restrict drug absorption.

A number of factors, including the pharmacological and physiological barriers, influence the repeatability of drug delivery in the lungs.

Delivery devices are needed to target medication delivery in addition to the lungs being an accessible surface for the drug delivery complex.

Both the substance and the ingredients added to the dosage form include the potential of causing local side effects and permanent damage to the cilia on the nasal mucosa.

At high concentrations, several surfactants that are used as chemical enhancers have the potential to destabilize and even dissolve membranes.

If the dosage form is administered improperly, there may be a mechanical loss of the medication into the lungs or other respiratory tract sections.

DOSAGE FORM IN NASO-PULMONARY DRUG DELIVERY SYSTEM

Nasal drops

They are the most practical and straightforward nasal medication delivery method yet created. Nose drops can be administered by a pipette or container. These drug combinations are frequently suggested for the treatment of regional ailments, encompassing issues like microbial proliferation, dysfunctional mucosa and non-specific loss of the lower back or nose. This system's main drawback is its lack of dose precision, which means nasal drops could not be helpful for prescription medications. According to reports, nasal drops work better than nasal sprays at depositing human serum albumin in the nostrils[20].

Nasal sprays

Nasal sprays are made of a combination of solution and suspension. With the availability of actuators and metered dose pumps, a nasal spray can precisely administer a dosage ranging from 25 to 200μm. The choice of pump and actuator assembly is determined by the formulation's viscosity and the drug's shape and particle size (for suspensions)[21].

Nasal gels

There wasn't much interest in this method until the development of the precise dosage device recently. Nasal gels are thickened liquids or suspensions with a high viscosity. A nasal gel's high viscosity reduces post-nasal drip; it also lessens the impact of taste because swallowing is reduced; it reduces anterior formulation leakage; it reduces irritation by using soothing and emollient excipients; and it targets the mucosa for higher absorption[22].

Nasal powder

If dosage forms in the form of solutions and suspensions cannot be prepared, for whatever reason—such as inadequate drug stability-this dosage form may be developed. The lack of better stability and formulation preservative is an advantage of the nasal powder dosage form. However, the solubility, particle size, aerodynamic characteristics, and nasal irritancy of the active medication and excipients determine how appropriate the powder formulation is. One more benefit of this approach is that the medication can be applied locally[22].

Liposomes

Phospholipid vesicles consist of a bilayer that encloses one or more aqueous compartments where a medication can be adsorbed or entrapped.

Microspheres

In addition to improving absorption and prolonged release, microspheres are crucial for nasal drug delivery because they shield the medication from enzymatic degradation[21].

Instillation and rhinyle catheter

To easily administer the drops to a specific area of the nasal cavity, catheters are used. Fill the tube with the formulation, place one end in the nose, and blow through the other end using your mouth to get the solution into your nasal cavity. Catheter dosing is based on system precision and filling before delivery; this is primarily utilized for experimental research only[22].

Compressed air nebulizers

A nebulizer is a device that is used to inhale a medicine mist into the lungs. The gadget is filled with compressed air, hence the name "compressed air nebulizers." All nebulizers have the same basic principle, which involves using compressed air, oxygen, or ultrasonic power to disperse medical treatments or suspensions into tiny aerosol droplets that can be inhaled directly from the mouthpiece of the device. When using a nebulizer, the medication is usually placed into the device in the form of a liquid solution. Salbutamol (Albuterol USAN), a bronchodilator and corticosteroid, is frequently used, occasionally in conjunction with ipratropium.

These medications are inhaled rather than swallowed because this allows them to target the respiratory tract, which decreases side effects and speeds up the medication's beginning of action as compared to other consumption methods. The systemic administration of medication by the patient alone is not appropriate for this device[23].

Squeezed bottle

Decongestants are primarily delivered by squeezed nasal bottles. One of them is a sleek plastic bottle with a basic jet outlet. A specific volume is atomized when the plastic bottle is pushed because the air inside the container is forced out of the tiny nozzle. Air is pulled into the bottle by releasing the pressure once more. This process frequently causes nasal secretions to be drawn within and bacteria to contaminate the fluids. Squeezed nasal bottles administer liquids and the deposition and accuracy of the dose depend greatly on the route of delivery. The formulation's dosage and droplet size are affected by the distinctions between applications that are softly pressed and those that are forcefully pushed. So, it is difficult to regulate the dosage. Consequently, it is not advised to use squeezed bottles with vasoconstrictors.

Insufflators

The devices known as insufflators are used to provide drugs for inhalation; they can be made by inserting the drug into a straw or tube, and occasionally they additionally include a syringe. Due to inadequate particle disaggregation, the realized particle size of these systems is frequently larger than the powder particle size, which causes a significant coefficient of variation for the initial deposition regions. Pre-dosed powder doses in capsule form are used by several insufflator systems[24].

Dry powder inhaler

Devices known as dry powder inhalers (DPIs) are used to administer an active medication in a dry powder formulation via the pulmonary route for either local or systemic effects. A solid medication that has been suspended or dissolved in a non-polar volatile propellant or in a dry powder inhaler that becomes fluidized when the patient inhales is what is contained in dry powder inhalers, which are bolus drug delivery devices. They have also been used to treat diabetes mellitus. These are frequently used to treat respiratory conditions such asthma, bronchitis, emphysema and COPD.

Typically, the drug is stored in an inhaler's unique form or in a capsule that can be manually loaded. After loading or activating the device, the user inserts the mouthpiece into their mouth, inhales deeply and holds their breath for five to ten seconds. These kinds of devices are numerous. Larger powder doses have the potential to provoke coughing, therefore the maximum quantity that can be administered in a single breath is usually less than a few tens of milligrams[24].

Pressurized MDIs

With the help of a metered-dose inhaler (MDI), a patient can inhale a brief aerosolized medicine burst that contains a predetermined amount of medication. When treating respiratory conditions like asthma, chronic obstructive pulmonary disease (COPD), and others, this is the most widely used administration method. When treating asthma and COPD, the drug in a metered dose inhaler is typically a bronchodilator, corticosteroid, or a combination of the two. Other less often used drugs that are also given by MDI are mast cell stabilizers, like nedocromil or cromoglicate.

The benefits of MDIs include their small size and portability, availability across a broad dosage range per actuation, dose accuracy and consistency, content protection, and speedy readiness for use[24].

PROSPECTIVE USES FOR NASOPHARYNGEAL DRUG DELIVERY SYSTEMS

Because nasopulmonary drug delivery devices effectively target both the upper and lower respiratory tracts, they hold great promise for a variety of therapeutic applications. Treatment of respiratory conditions such cystic fibrosis, asthma, and chronic obstructive pulmonary disease (COPD) is one possible use. Nasopulmonary drug delivery systems (NDDS) have several possible uses, such as:

Local medication delivery to the nose and lungs

NDDS is a useful tool for treating a range of respiratory ailments, including infections, allergies, COPD and asthma.

Systemic delivery

NDDS can also be used to administer medications in a way that distributes them throughout the body by absorbing them into the bloodstream. Drugs that must be administered fast or that are not well absorbed from the stomach may benefit from this.

Delivery to the brain

Drug delivery straight to the brain is another application for NDDS. Brain tumors, Alzheimer's disease, and Parkinson's disease may all benefit from this treatment[25-27].

Nasopulmonary therapy is helpful for treating a number of diseases through the nasal route of drug delivery:

Respiratory Disorder Treatment

Nasopulmonary drug delivery systems (NDDS) represent a novel and exciting therapeutic option for the management of respiratory conditions. Drugs can be administered via NDDS straight to the lungs and nose, where they can act locally or enter the bloodstream.

NPDDS are being utilized to treat a range of respiratory conditions, such as:

Asthma

A range of asthma treatments, including bronchodilators, corticosteroids and anti-inflammatory agents, can be administered via NDDS. It has been demonstrated that NDDS is useful in easing the symptoms of asthma and enhancing lung function.

Chronic obstructive pulmonary disease (COPD)

For the treatment of chronic obstructive pulmonary disease (COPD), NDDS can be used to provide bronchodilators as well as other drugs. It has been demonstrated that NDDS helps COPD patients live better and function better in their lungs.

Cystic fibrosis

Antibiotics and other drugs can be administered by NDDS to treat cystic fibrosis. In patients with cystic fibrosis, NDDS have been demonstrated to enhance lung function and lower the frequency of exacerbations.

Lung cancer

The delivery of chemotherapeutic medications for the treatment of lung cancer is being studied with NDDS. NDDS may lessen side effects and increase the effectiveness of chemotherapy[27].

Furthermore, NDDS are being studied for the treatment of neurological illnesses, diabetes, and pain in addition to the respiratory disorders mentioned above.

Systemic drug delivery

The act of administering medication to the bloodstream via the nose and lungs is known as systemic drug delivery in nasopulmonary drug delivery systems (NDDS). There are two methods to accomplish this:

Direct absorption

Through the mucosa of the nose and lungs, medications can enter the bloodstream directly. Peptides, proteins, and tiny molecules can all be delivered using this method, which is comparatively quick and effective.

Enhanced absorption

By making the nasal and pulmonary mucosa more permeable, absorption enhancers can help the body absorb more big molecules and medications that are not well absorbed passively.

NDDS systemic drug delivery offers several benefits over conventional drug delivery techniques including parenteral and oral administration. Among these benefits are:

Fast onset of effect

Medication administered by NDDS has a fast start of action since it can be swiftly absorbed into the bloodstream. Treatment of acute disorders including pain and allergic responses depends on this.

High bioavailability

Medications administered via NDDS have the potential to have high bioavailability, which entails a high rate of drug absorption into the bloodstream. This is crucial for medications like insulin that are not well absorbed from the stomach.

Administration without invasiveness

Since NDDS are non-invasive, no needles or injections are needed. Patients will find them more convenient and acceptable as a result.

Decreased side effects

By avoiding the first-pass metabolism and administering medications straight to the bloodstream, NDDS can lessen unwanted effects. This is crucial for medications with a high rate of adverse effects, as those used in chemotherapy.

Although systemic drug delivery using NDDS is currently in the early stages of research and development, it has the potential to completely change how medications are administered for a variety of illnesses. Several medications, including insulin, analgesics, vaccines, anticancer medications, gene therapies, peptide pharmaceuticals and protein therapeutics, are being studied for systemic distribution via non-directed drug delivery systems. For the systemic distribution of a variety of medications, NDDS present a promising new strategy[27-30].

Immunotherapy and vaccination

Nasopulmonary drug delivery systems (NDDS) are a novel and exciting method for administering immunotherapies and vaccinations. Drugs can be administered via NDDS straight to the lungs and nose, where they can either function locally to boost the immune system or be absorbed into the bloodstream.

Compared to more conventional immunization techniques, including injectable vaccinations, NDDS have several advantages. Among these benefits are

Administration without invasiveness

Since NDDS are non-invasive, no needles or injections are needed. Patients find them more acceptable and handy as a result, particularly young patients and those who are needle-phobic.

Quick action

NDDS has the ability to quickly introduce vaccinations into the immune system, causing immunity to develop more quickly. This holds significance for vaccinations targeting newly developing infectious diseases like COVID-19.

Enhanced mucosal immunity

Vaccines can be administered via NDDS to the nasal and pulmonary mucosal surfaces, where they can create robust mucosal immunity. Protecting against respiratory infections requires mucosal immunity.

Decreased side effects

By avoiding the first-pass metabolism and administering vaccinations straight to the immune system, NDDS can lessen unwanted effects. This is crucial for vaccinations like live attenuated vaccines, which have a high rate of adverse effects[31].

Additionally, the administration of immunotherapies such checkpoint inhibitors and cancer vaccines is being studied for NDDS.

FUTURE PERSPECTIVES AND CHALLENGES

With several possible uses, NDDS is a drug delivery system that shows promise. NDDS has a bright future ahead of it, and in the years to come, major advancements in this subject should be expected. The following are some major themes that could influence how NDDS develops in the future:

Expanded application of nanotechnology

Nanomaterials can enhance drug solubility, permeability, and targeting, among other benefits for NDDS. In the future, we should anticipate seeing more nanomaterials used in the creation of new NDDS systems.

Creation of individualized NDDS systems

These systems can be modified to meet the unique requirements of every patient. This can be accomplished by accounting for variables including the patient's age, sex and state of illness. In the future, we should anticipate seeing more customized NDDS systems being created.

Use of NDDS systems for complex drug delivery

Complex medications, such proteins and vaccines, that are challenging to provide via conventional routes of administration, can be delivered via NDDS systems. In the future, we should anticipate seeing NDDS employed to provide a progressively greater variety of complex medications[32].

The following are some potential future developments for the nasal medication delivery system

Regulatory Aspects and Safety Characteristics

It is crucial to address regulatory considerations and guarantee the safety profiles of nasopulmonary medication delivery systems. This expert discussion seeks to clarify the significance of following legal requirements and upholding a strong safety profile in the creation and application of these systems.

The US Food and Drug Administration (FDA) oversees nasal drug delivery systems (NDDS) as medical devices. For its intended usage, NDDS must be both safe and effective, according to the FDA. In general, NDDS has a decent safety record. Notwithstanding, there exist certain possible adverse reactions, including but not limited to nasal mucosal irritation, nasal dryness, sneezing, headache, nosebleed, and coughing. Rarely, more severe side effects include allergic reactions, elevated intracranial pressure, and seizures might be brought on by NDDS.

As nasopulmonary medication delivery devices are developed and used, regulatory considerations and safety profiles are essential. Ensuring the effectiveness, quality, and safety of these systems requires strict adherence to regulatory requirements and the completion of thorough safety assessments. Drug distribution can be advanced and patient care improved by putting a high priority on regulatory compliance and upholding strong safety profiles[33].

CONCLUSION

With several possible uses, NDDS is a drug delivery system that shows promise. NDDS has a bright future ahead of it and in the years to come, major advancements in this subject should be expected. Many benefits are associated with the nasopulmonary route, such as non-invasive administration, quick absorption and avoidance of first-pass metabolism. In addition, the nasal cavity's abundant blood supply and vast surface area make it a perfect delivery channel for systemic medications. However, in order to maximize the effectiveness of this delivery system, issues including nasal mucociliary clearance and restricted drug permeability need to be resolved. The nasopulmonary route has enormous potential for the delivery of drugs in the future due to continuous developments in formulation technologies and nasal drug delivery devices. In order to fully realize the promise of this method and convert it into therapeutic applications, more investigation and development work are required.

ACKNOWLEDGEMENT

The authors wish to express their sincere gratitude to Faculty of Pharmaceutical Sciences, Mahayogi University, Gorakhpur, Uttar Pradesh, India for providing necessary facilities to carry out this review work.

CONFLICT OF INTEREST

We declare that we have no conflict of interest.

BIBLIOGRAPHY

1. Ibrahim A, Aziz O A A, Dena A S A, El-Sherbiny I M. Current advancements in nasopulmonary drug delivery systems, *In Advanced and Modern Approaches for Drug Delivery*, 2023, 91-111.
2. Chaudhari R, Deshmukh A, Sahu V, Pharm B, Pote P R. NASO pulmonary drug delivery system-A novel approach, *World J Pharmaceut Res,* 9(15), 2020, 542-558.
3. Kumbhalkar P R, Mustafa S S M, Ramchandani T K, Ramani M S, Kadak S A, Shaikh A S, Khan T J, Zodape P M. A review on inhalation drug delivery system, *IRJMETS*, 5(12), 2023, 1155-1161.
4. Pal R, Pandey P, Nogai L, Anand A, Suthar P, Sahdev Keskar M, Kumar V. The future perspectives and novel approach on gastro retentive drug delivery system (GRDDS) with currrent state, *Journal of Population Therapeutics and Clinical Pharma,* 30(17), 2023, 594-613.
5. Appasaheb P S, Manohar S D, Bhanudas S R, Anjaneri N. A review on intranasal drug delivery system, *Journal of Advanced Pharmacy Education and Research,* 3(4), 2012, 333-346.
6. Geurkink N, Akwete A L, Zironi E, Bortolotti F. Nasal anatomy, physiology and function, *J Allergy Clin Immunol*, 72(2), 1983, 123-128.
7. Illum L, Jorgensen H, Bisgard, Hand Rossing N. Bioadhesive microspheres as a potential nasal drug delivery system, *Int. J. of Pharmaceutics,* 40(5), 2014, 189-199.
8. Pal R, Pandey P, Nogai L. The advanced approach in the development of targeted drug delivery (TDD) with their biomedical applications: A descriptive review, *International Neurourology Journal*, 27(4), 2023, 40-58.
9. Serralheiro A, Alves G, Sousa J, Fortuna A, Falcao A. Nose as a route for drug delivery, *Nasal Physiology and Pathophysiology of Nasal Disorders,* 2013, 191-215.
10. Alabsi W, Eedara B B, Encinas-Basurto D, Polt R, Mansour H M. Nose-to-brain delivery of therapeutic peptides as nasal aerosols, *Pharmaceutics,* 14(9), 2023, 1870.

11. Handa M, Yadav A K, Almalki W H, Alghamdi S, Alharbi K S, Beg S. Therapeutic potential of nanoemulsions as feasible wagons for targeting Alzheimer's disease, *Drug Discovery Today,* 26(12), 2021, 2881-2888.
12. Aulton M E, Adhikrao V Y, Niven, Ando H. The science of dosage form design, *Churchill Livingston, Pharmaceutic, New York,* 11(6), 2002, 494-498.
13. Ozer A Y, Akwete A L, Zironi E, Bawarshi R N. The importance of intranasal route for application of drugs and nasal drug delivery systems, *Pharm JTPA,* 30(9), 1990, 136-147.
14. Kaye R S, Purewal T S, Alpar O H, Jorgensen. Development and testing of particulate formulations for the nasal delivery of antibodies, *J Control Release,* 135(12), 2009, 127-135.
15. Satish B B, Adhikrao V Y, Amelia M A, Rajkumar M. Bio availability of intranasal drug delivery system, *Asian J of Pharmaceutic,* 8(1), 2008, 201-215.
16. Newhouse M T, Bortolotti F, Lorenzini L, Akwete A L. Advantages of pressured canister me-tered dose inhalers, *J. Aerosol Med,* 4(2), 1991, 139-150.
17. Akwete A L, Gupta P K, Niven, Bawarshi R N. Delivery of biotherapeutics by inhalation aerosol, inhalation delivery of therapeutic peptides and proteins, *Marcel Dekker Inc, New York,* 5(2), 1997, 151-231.
18. Serralheiro A, Alves G, Sousa J, Fortuna A, Falcao A. Nose as a route for drug delivery, *Nasal Physiology and Pathophysiology of Nasal Disorders,* 2013, 191-215.
19. Jadhav T, Sarode R, Biyani K R. A review on Naso-pulmonary drug delivery system, *European Journal of Pharmaceutical and Medical Research,* 8(5), 2021, 345-351.
20. Rudman K L, O'Brien E K, Leopold D A. Radiographic distribution of drops and sprays within the sinonasal cavities, *Am J Rhinol Allergy,* 25(2), 2011, 94-97.
21. Suber C, Elsner P, Farage M A. Topical application and the Mocosa, *Curr Probl Dermatol, Basal, Kerger,* 40, 2011, 20-35.
22. Shyeilla V D, William H F. Intranasal delivery to the central nervous system: Mechanisms and experimental considerations, *J Pharma Sci,* 99(4), 2010, 1654-1673.
23. Merkis F W, Van Den Berg M P. Can nasal drug delivery bypass the blood barrier? Questioning the direct transport theory, *Drug R D,* 8(3), 2007, 133-144.
24. Thulasiramarajun T V, *et al*. Pulmonary drug delivery system: An overview, *Asian Journal of Research in Pharmaceutical Science and Biotechnology,* 1(1), 2013, 16-34.
25. Gupta H, Sharma A. Recent trends in protein and peptide drug delivery systems, *Asian Journal of Pharmaceutics (AJP),* 3(2), 2009.
26. Pandey P, Pal R, Bharath K S, Akilandeshwari A, Koli M, Rizwan M, Chawra H S. Design of Experiments (DOE) manipulation in the formulation and optimization of a traditional ayurvedic medicine derived from dried extract of Senegalia catechu enhanced through statistical analysis, *Journal of Pharmacognosy and Phytochemistry,* 12(6), 2023, 159-169.
27. Pandey P, Pal R, Thakur S K, Sharma V, Chanana A, Singh R. Future aspects and modification in carbon nanoparticles in treatment and diagnosis, *World Journal of Pharmacy and Pharmaceutical Sciences,* 12(2), 2022, 307-324.
28. Sangolkar S, Adhao V, Mundhe D, Sawarkar H. Particle size determination of nasal drug delivery system: A review, *Int. J. Pharm. Sci. Rev. Res,* 17(1), 2012, 66-73.
29. Virmani T, Gupta J. Pharmaceutical application of microspheres: An approach for the treatment of various diseases, *Int J Pharm Sci Res,* 8(8), 2017, 3253-3260.
30. Courtney A U, McCarter D F, Pollart S M. Childhood asthma: Treatment update, *American Family Physician,* 71(10), 2005, 1959-1968
31. Bridgeman M B. Overcoming barriers to intranasal corticosteroid use in patients with uncontrolled allergic rhinitis, *Integrated Pharmacy Research and Practice,* 6, 2017, 109-119.

32. Couroux P, Kunjibettu S, Hall N, Wingertzahn M A. Onset of action of ciclesonide once daily in the treatment of seasonal allergic rhinitis, *Annals of Allergy, Asthma and Immunology*, 102(1), 2009, 62-68.
33. Lareau S C, Fahy B, Meek P, Wang A. Chronic obstructive pulmonary disease (COPD), *American Journal of Respiratory and Critical Care Medicine*, 199(1), 2019, P1-P2.

Please cite this article in press as: Shweta Yadav *et al*. Nasopulmonary medication delivery systems: A review, *Asian Journal of Research in Biological and Pharmaceutical Sciences*, 11(3), 2023, 69-79.