



Review On Nebulizers.

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ABSTRACT: Inhalation therapy is essential in managing chronic obstructive pulmonary disease (COPD). For patients who cannot effectively use handheld inhalers—such as the elderly or those with poor coordination—home nebulization therapy provides an effective alternative. Nebulizers convert liquid medication into aerosols suitable for inhalation, enabling efficient drug delivery to the lungs and allowing larger doses than handheld inhalers. Modern “smart” nebulizers, such as I-neb and AKITA, can sense a patient’s breathing pattern and release medication accordingly, reducing drug wastage. Nebulizers are available in small-volume (5–20 mL) and large-volume (up to 200 mL) formats, depending on the therapy type. Proper patient selection, device maintenance, and cleaning are crucial for effective home nebulization. The increasing prevalence of COPD and asthma, along with advancements in smart nebulizer technology and microparticle formulations, continue to drive growth and innovation in this field .

KEY WORDS: Chronic obstructive pulmonary disease, home nebulization, inhalation therapy, maintenance nebulization, nebulization, nebulizer.

INTRODUCTION.

Inhalation therapy continues to be a fundamental approach in the management of obstructive airway disorders, particularly chronic obstructive pulmonary disease (COPD). With the growing prevalence of respiratory diseases, there has been a corresponding rise in both the diversity and number of inhalation devices available for their treatment in recent years. Each device employs a unique aerosol generation mechanism, which influences the inhalation technique that patients must use to ensure efficient drug delivery. Research indicates that, when operated correctly, all major types of inhalation devices demonstrate comparable clinical efficacy. However, numerous real-world studies have emphasized that a patient’s ability to correctly use the device plays a decisive role in achieving optimal lung drug deposition and effective disease control.

Among the commonly used inhalation systems—pressurized metered-dose inhalers (PMDIs), dry powder inhalers (DPIs), and breath-actuated inhalers—nebulizers are regarded as the simplest to operate. Their use demands minimal hand–breath coordination, manual dexterity, or physical effort, making them ideal for patients with limited cognitive or physical capability. With technological innovations, nebulizers have become more compact, portable, and user-friendly. Additionally, a wide range of medications—including long-acting beta₂-agonists (LABAs), long-acting muscarinic antagonists, corticosteroids, mucolytics, and antibiotics—are now available in nebulized formulations. These developments have extended the role of nebulizers beyond acute care environments such as clinics and hospitals, enabling their use in home-based therapy.

Market analyses and published literature reveal a steady increase in home nebulizer use, particularly among elderly COPD patients, which underscores the need to better understand their effectiveness, practicality, and implications in the current healthcare context. When prescribed for home management, nebulizers warrant careful selection and monitoring since patients operate them independently, unlike in supervised clinical settings. Although abundant research exists on nebulization therapy in general, there remains a lack

of detailed reviews focusing specifically on long-term or maintenance home nebulization for COPD management.

The term “maintenance nebulization” typically refers to the continuous use of nebulizer therapy at home for more than three weeks, whereas “home nebulization” is a broader concept encompassing both short- and long-term applications.

This review aims to explore critical aspects of home nebulization as a maintenance therapy in COPD, including: (a) identifying appropriate patient candidates; (b) understanding the perspectives of patients and caregivers regarding home nebulizer use; (c) reviewing medications approved for nebulization in COPD; (d) examining factors influencing the selection of nebulizer devices and their accessories; and (e) outlining recommended practices for the cleaning, maintenance, and care of nebulizers. Ultimately, this review seeks to aid clinicians in guiding COPD patients toward effective long-term disease management through structured home-based nebulization therapy.

NEBULIZERS.

Several types of devices are available for pulmonary drug delivery (PDD), such as nebulizers, dry powder inhalers (DPIs), and pressurized metered-dose inhalers (PMDIs). These devices are widely employed not only in the treatment of common respiratory illnesses like asthma and chronic obstructive pulmonary disease (COPD), but also for managing conditions such as respiratory syncytial virus (RSV) infections, tuberculosis, influenza, schizophrenia, and various other pulmonary disorders.

However, elderly individuals and infants often face difficulties in using PMDIs correctly, and patients with physical limitations such as arthritis may also struggle with handheld inhalers. A survey conducted in the United States and Europe showed that nebulizers are preferred over PMDIs with spacers for children aged 1 to 5 years.

Nebulizers are devices that convert liquid medications into fine aerosol droplets suitable for inhalation, allowing efficient drug deposition in the lungs.

CLASSIFICATION OF NEBULIZERS:

In the market various types of nebulizers are present. Fig. 1 depicts the various types of nebulizers.

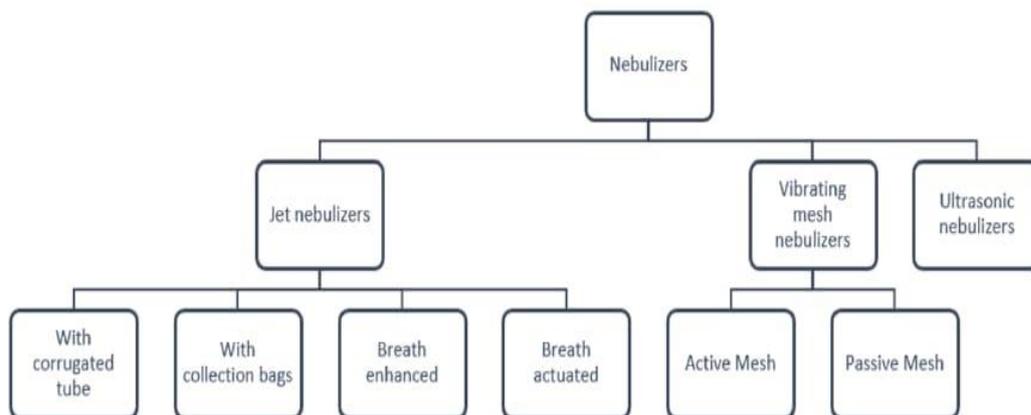


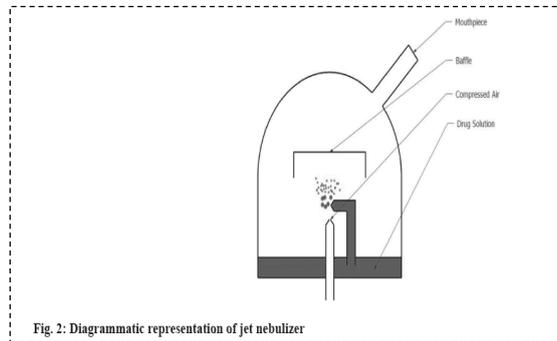
Fig. 1: Classification of nebulizers

1. Jet Nebulizers.

Jet nebulizers generate aerosols using a stream of gas. The gas, which can come from a compressed source or an electrically operated compressor, typically flows at a rate of 6–10 L/min. The drug solution from the nebulizer’s reservoir is drawn into a capillary tube, where it is transformed into aerosol particles. The baffles within the device help reduce particle size by impaction, as represented in Figure 2.

Also referred to as pneumatic nebulizers, jet nebulizers are useful for delivering antibiotics, mucolytics, and liposomal formulations that cannot be administered via DPIs or PMDIs. Despite their effectiveness, they often show low drug delivery efficiency and considerable medication loss. To improve performance, several design modifications have been introduced, resulting in four main types of jet nebulizers:

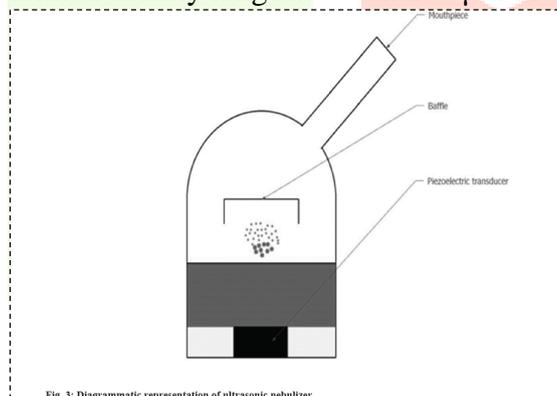
- i. Jet nebulizers with corrugated tubing.
- ii. Jet nebulizers with a collection bag.
- iii. Breath-actuated nebulizers.
- iv. Breath-enhanced nebulizers.



2. Ultrasonic Nebulizer.

Ultrasonic nebulizers operate on the concept of ultrasonic atomization. In this process, a thin layer of liquid moves across a vibrating surface that oscillates at a frequency above 20 kHz, causing the liquid to break up into fine droplets. These devices were first introduced in the 1960s to overcome the drawbacks of traditional jet nebulizers. Compared to jet nebulizers, ultrasonic models are smaller, quieter during operation, and provide a higher aerosol output. The main parts of an ultrasonic nebulizer are depicted in Figure 3. However, the level of drug deposition in the lungs remains comparable to that achieved with jet nebulizers.

A piezoelectric crystal or disc acts as the vibrating element, generating ultrasonic vibrations that travel through the liquid to its surface. These vibrations create standing waves, which then collapse and release a fine mist. The aerosol droplets formed usually range between 2–4 μm in size.



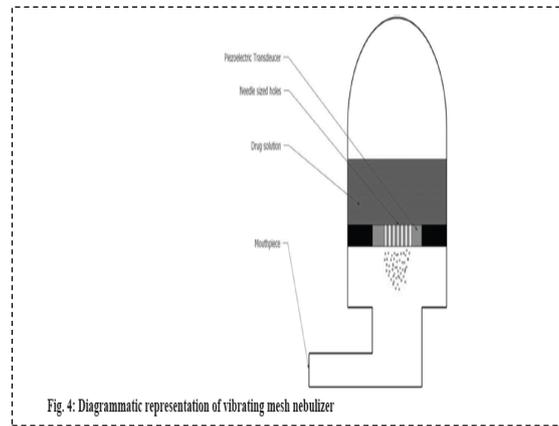
3. Vibrating Mesh Nebulizer.

Progress in nebulizer design and technology has led to the development of vibrating mesh nebulizers. These devices make use of micropump technology, where the liquid medication is pushed through a fine mesh to generate aerosols, as illustrated in Figure 4. Depending on the manufacturer, these nebulizers may be battery-operated or electrically powered. This mechanism allows for the production of aerosol particles with controlled sizes that can effectively reach specific regions of the respiratory tract.

The efficiency of a vibrating mesh nebulizer depends on parameters such as the vibration type, mesh design, and the material used to make the mesh. Compared to both jet and ultrasonic nebulizers, vibrating mesh types produce finer and more uniform aerosol particles, resulting in improved delivery efficiency.

Studies have shown that vibrating mesh nebulizers exhibit better anatomical selectivity than jet nebulizers. Although both nasal jet and nasal mesh nebulizers generate aerosols of comparable particle size, the latter

demonstrates significantly greater peripheral aerosol deposition within the nasal cavity, while minimizing drug loss in the lungs.



DRUGS USED AND APPROVED FOR NEBULIZATION THERAPY IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE.

The nebulized drugs used in COPD fall into the different categories, as listed in table 1.

Drug class	Molecules	Recommended use (in adults)*
SABA	Salbutamol levosalbutamol	As-needed use in OADs
LABA	Arformoterol	Long-term maintenance in COPD
SAMA	Ipratropium bromide	Long-term maintenance in COPD
LAMA	Glycopyrronium bromide	Long-term maintenance in COPD
SABA+SAMA	Salbutamol+ipratropium Levosalbutamol+ipratropium	Long-term maintenance in COPD/as-needed use in maintenance regimen in COPD
ICS+LABA	Budesonide+formoterol	Long-term maintenance in OAD
Mucolytics	N-acetylcysteine ambroxol	Short term adjuvant use in OAD in case of mucus hypersecretion

COMPARISON BETWEEN JET, ULTRASONIC, AND MESH NEBULIZERS.

Table 2.

Parameters	Jet	Ultrasonic	Mesh
Power source	Electric/compressed gas (i.e., oxygen)/battery	Electric/battery	Battery/electric
Principle	Compressed air technology	High frequency sound waves	Static/vibrating mesh
Treatment time	~10–15 min	4–10 min	1–5 min
Output rate	Low	Higher	Highest
Cleaning	After every use	After several uses	After every use
Cost	Low	High	High
Drug formulations	Can nebulize solutions, suspensions, oils	Cannot nebulize suspensions or liquids with high viscosity/surface tension	Some cannot nebulize suspensions with high viscosity/surface tension
Portability	Limited	Limited	Portable
Sound	Noisy	Silent	Low/silent
Parameters	Jet	Ultrasonic	Mesh

ADVANTAGES AND DISADVANTAGES.

The pros and cons of all the above discussed nebulizers are mentioned in Table 3.

Jet nebulizers	Easy to use Minimum cognitive ability required	Long administration time Less portability
Ultrasonic nebulizers	Large volumes of liquid can be nebulized Shorter delivery time than jet	Lower efficiency May breakdown complex molecules
Vibrating mesh nebulizers	Short administration time More portable	Frequent cleaning is required Limited medications can be administered

CARE, CLEANING, AND MAINTENANCE OF NEBULIZERS.

Proper cleaning and maintenance of nebulizers are essential for successful home-based COPD therapy. Educating patients and caregivers about correct cleaning, disinfection, and maintenance practices is crucial for preventing infections. Failure to regularly disinfect nebulizer components can lead to bacterial contamination and may worsen respiratory health or lung function in COPD patients.

A study by Della Zuana et al. demonstrated that a single educational session—providing both oral and written instructions—significantly improved cleaning and maintenance habits among home nebulizer users. This intervention led to a 43% reduction in contaminated nebulizers. Regular follow-up and

reassessment of patients receiving nebulization therapy (ideally every six months) are also recommended to ensure optimal therapeutic outcomes and continued safety.

PERCEPTIONS OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS AND CAREGIVERS ON HOME USE OF NEBULIZERS.

According to a study by Sharafkhaneh et al., the majority of COPD patients and caregivers (89% and 92%, respectively) reported being “generally satisfied” with the ongoing nebulization therapy. Nearly 80% of both groups believed nebulizer use was more effective than inhaler therapy (PMDI/DPI). Moreover, 79% of patients and 85% of caregivers agreed that the benefits of nebulization outweighed any associated inconveniences. Many patients also noted improvements in quality of life (75% positive responses) and greater ease of care for caregivers (77% positive responses).

Similarly, a survey conducted by Barta et al. revealed comparable findings—patients experienced improved symptom control, enhanced independence, better functioning than with inhalers, increased confidence, and reduced hospital visits. Nevertheless, some participants mentioned drawbacks such as dependence on the nebulizer, longer treatment duration, limited portability, and occasional embarrassment during use. A few also reported challenges related to proper cleaning and disinfection of nebulizer parts.

I.CONCLUSION

PDDS offers many advantages over the conventional systems. PDDS can be achieved using nebulizers, DPI and other inhalers. However, nebulizers are more efficient in COPD and asthma as well as for infants and older patients. Nebulizers have evolved from the basic jet to completely automated smart nebulizers. This development has helped in achieving more accurate dose and minimizing drug wastage. Even with these advancements in nebulization technology popular nebulizers in the market include the basic and inexpensive devices, owing to the higher cost of the advanced nebulizers. Thus, a combination of an efficient smart and economical nebulizer along with a micro particle drug formulation may augment the drug action and a desirable outcome can be achieved.

Prescribing the appropriate inhalation therapy to COPD patients should be based on various factors such as the patient's ability to use the device, patient's lung function, physical and cognitive skills, and individual preference. It is common in routine practice to encounter COPD patients who are unable to optimally use handheld inhalers because of physical or cognitive impairments and/or with poor lung condition. Treatment options such as nebulization, which do not require coordination of actuation and inhalation or an inspiratory flow threshold, represent a promising suitable alternative in such patients. Benefits of nebulization therapy can be optimized through careful patient selection, prescribing the appropriate drug regimen and nebulizer, counselling the patient and caregivers on the disease, and regular assessment and follow-up checks.

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