

Review on Nebulizer

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Abstract—Nebulizers have played a pivotal role in respiratory care, providing an effective means of delivering medications directly to the lungs. This review explores the historical evolution of nebulizers, tracing their origins from early inhalation practices to the development of modern devices. Various types of nebulizers, including jet, ultrasonic, and vibrating mesh systems, are discussed with emphasis on their mechanisms, advantages, and limitations. The article also highlights ongoing innovations and future prospects, such as smart nebulizers, portable designs, and integration with digital health platforms for personalized therapy. By combining insights from history, current technologies, and emerging trends, this review underscores the importance of nebulizers in shaping the present and future of inhalation therapy.

Index Terms—Advancement, applications, Nebulizers. Respiratory disease, therapy

I. INTRODUCTION

A nebulizer is a medical device that converts liquid medicine into a mist and tiny water droplets suspended air. The device is directly deliver the medicine to the lungs With the help of breathing to treat asthma, COPD and breathing problems. In nebulizer the fine mist is enters through breathing by mask or mouthpiece. Nebulizer making easier to deliver direct relief by the inhalation. Inhalation therapy has existed from people in ancient India inhaling Datura smoke 4,000 years ago, to today's smart inhalers. Over time, people used clay inhalers, plant extracts, stramonium cigarettes, and later nebulizers. The first nebulizer came in 1956 since then; science and technology have made inhalers and nebulizers according to convenience for use. Nebuliser helps doctors to monitoring the patient[1,3]

Historical Background – [2]

Time period	Development/Practice	Details/Significance
200 BCE (Ancient India)	Use of <i>Datura</i> preparation	First known inhalation therapy for respiratory problems
18th–19th century	Earthenware inhaler	Used plant-extract-infused air for inhalaion
Mid 19th century (France)	Atomizers and Nebulizer	Inspired by perfume inustry and thermal water inhalation at spas
Early 20th century	Combustible powders and cigarettes (Stramonium)	commonly used to treat asthma and breathing disorders
Early–Mid century	Discovery of epinephrine	Marked a major step in asthma treatment
1956	Hand-bulb and compressor nebulizers	Allowed delivery of drugs directly into the lungs
1960s–1980s	First pressurized dose inhaler	For epinephrine and isoproterenol; revolutionized therapy
1987	Advances in device technology and formulation	Improved particle sizing, deposition studies pharmacokinetics & pharmaco
Late 20th century – Present	Modern inhaler	Banned CFC propellants: safer inhaler propellants introduced
21st century	Smart inhalers & digital health integration	Enable personalized medicine, connectiv and remote

Table no. I

II. TYPES OF NEBULIZERS

1) Jet nebulizer:

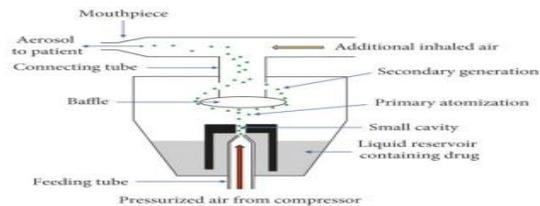


Fig. no. I Jet nebulizer[5]

For years, jet nebulizers have been used in treatment of various lung conditions, but let's be honest—they have not always been the most efficient. These devices rely on a steady stream of compressed gas (about 2 to 10 liters per minute) to transform liquid medication into a mist. The process consists of blasting the liquid by a tube & breaking it into tiny micro droplets, and then it filters out and only the finest particles reach your lungs. While they are best for delivering medication those other inhalers (like pMDIs or DPIs) can't handle—think antibiotics, mucus thinners, or specialized treatments like Pulmozyme. They also come with some demerits like they're bulky, need extra tubing, and let's not forget the hassle of setting

up a compressed gas source & nowadays studies show they're not always the most efficient at getting medication where it needs to go. But here's the good news: nebulizers have gotten smarter. Fine tiny particle size for better drug delivery to the lung, and even you can adjust the aerosol production depending on your breathing. This means a proper dose of drug actually reaches your lungs instead of escaping into the air.[4]

2) Ultrasonic Nebulizer

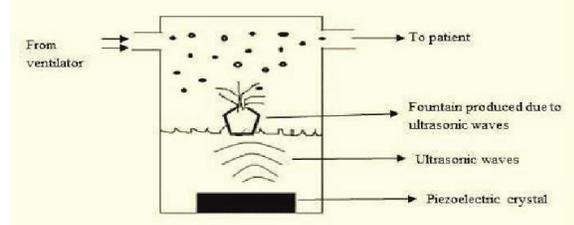


Fig. II Ultrasonic Nebulizer [6]

It is a modern device that uses high-frequency vibrations (thanks to a tiny piezoelectric crystal) to transform liquid medicine into mist—no noisy air compressor required. But while they're in a cool climate, they are not good for every medication.

It again has 2 types

1. Large-volume ultrasonic nebulizers – widely applicable for sputum tests (like when you need to cough up a sample after inhaling salty mist).

2. Small-volume ultrasonic nebulizers :- Designed for regular medicine, but along with some huge restrictions

It has 2 The Demerits:

1). Wasted more medicine (large amount of residue is left in the chamber)

2). Difficulty for thick or sticky solutions.

So while ultrasonic nebulizers are quite effective in some treatments, they're not the universal solution now until. Stick to jet nebulizers for thick or heat-sensitive nature of the medicine.[11]

3) Open-Vent Nebulizer.

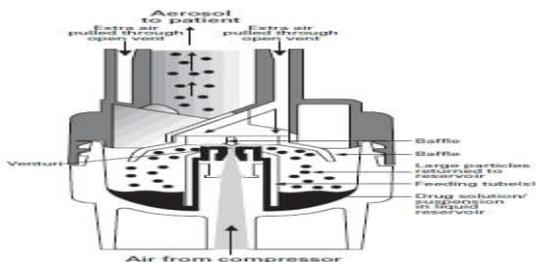


Fig no. III Open-Vent Nebulizer [7]

An open-vent nebulizer works similar to the standard jet nebulizer but with one major difference is that , it has a small opening near the top of the medicine cup. This opening inlet extra air mix in, creating a finer mist with tiny droplets, which can reach deeper into the lungs.

It worked by the following mechanism

1. Extra Airflow:- This opening allows more air to enter, helps to breakdown the medicine into tiny particles.

2. Better for Adults: - Due to its stronger airflow makes the mist easy to inhale deeply and because of this it's not mostly suitable for children

3. Faster Treatment: - its helps to instant critical condition Sometimes, but not for always its depends on the design. Sometimes it shows some drawbacks medicine lost, and some difficulties to inhale in the kids. Hence, To control the drawbacks another nebulizer is introduced A Solution that is the Intermittent Pari LL Nebulizer To fix this issue, some nebulizers (Pari LL) have a side button for controlling the airflow. This way parents or

- Less medicine is wasted.

- The treatment is gentler and more efficient.

It acts the following way

-Smart Valve System: A valve near the mouthpiece closes during inhalation (preventing drug loss) and opens during exhalation.

-Open Vent : An air vent at the top does the opposite— opening during inhalation to boost airflow and closing during exhalation.

- Synced Performance: Together, these features cut down on wasted aerosol and improve drug delivery.

Its Major Benefits are following :

1. Better Medication Delivery: More tiny droplets enter in the lungs, especially the smaller airways.

2. Efficiency: it works good even with low air pressure, making it cost-effective

3. Faster Treatment: For thicker (high-viscosity) medications, higher pressure reduces the nebulization time.

These Studies show this nebulizers deliver more medication to the lungs and act faster than traditional jet nebulizers.

Breath-Enhanced Open-Vent Nebulizer

Breath-enhanced open-vent nebulizers function similarly to standard open-vent nebulizers, consistently producing aerosol. But unlike traditional jet nebulizers, they're designed to reduce medication

loss especially during breathing It acts the following way

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4) Mesh Nebulizers:

It helps to Improving Aerosol Delivery for Infants and Children.

The introduction of mesh nebulizer technology has a modified way to medical aerosols which delivered to infants and young children, especially through nasal cannulas and prongs. Unlike older ultrasonic nebulizers, mesh nebulizers do not depend on compressed gas, making them small, light, and easy to integrate into breathing circuits. Before the 2000s, delivering aerosols to tiny infants (weighing just 1–4 kg) or animal models resulted in very little amount of medication reaching to the lungs—usually less than 5%. But thanks to modification in mesh technology and studies that show inhaled doses can increase by 14% or more, even when infants are on nasal continuous positive airway pressure (CPAP) ventilation. Adjacent researchers have discovered transnasal aerosol drug delivery through the different therapies, including:

-High-flow and low-flow oxygen through nasal cannula

-Nasal CPAP

-Noninvasive ventilation

mesh nebulizers have modified into a preferred choice for delivering expensive and sensitive nebulizer drugs. They outperform conventional jet nebulizers,

efficiency, and ease of use and making them popular in clinical trial especially for niche, high-cost therapies.

Major important merits:-

- Portable & silent operated by the battery and bulky compressor not required

- Energy-efficient less drug loss, faster delivery of medicine

-Precision dosing precise and standard dosing for expensive or sensitive medications

Market Growth:

Pharma preference: Mesh nebulizers dominate trials for specialized drugs.

Price low Competition and better tech are reducing costs.

Future scope in Expansion into home care and new therapies .

- Challenges:-

- Higher upfront cost

- Cleaning compatibility

5) Metered-Dose Inhalers (pMDIs): A Quick Guide

Pressurized metered-dose inhalers (pMDIs) these devices are used for delivering aerosolized medications, especially for respiratory conditions. They're popular because they're moveable, they don't need another power source, and supply an accurate dose of all time.

pMDIs is easy to handle due its handy inhalers it can deliver various types of medications, consists of :

Bronchodilators:- for faster relief in asthma , COPD or respiratory conditions)

Steroids & Anti-inflammatory drugs for prolong control

-Anticholinergics to help open airways by contraction of muscle in lungs

They act by the following mechanism

A pMDI is like a small pressurized canister filled with:

Propellants :- it helps to push the medication out from the device

Active drug:-only about 1% of the total mixture

Surfactants, preservatives, and flavoring agents are used to stabilize and improve taste

When you apply the pressure on the inhaler, the metering valve releases an exact dose by the actuator, creating a tiny mist you inhale. Thus the Even small

changes in the inhaler's design can give some adverse reaction on how well the medication is delivered is considered

Parts of a pMDI

1. Expansion Chamber :- it is the pMDI Where the drug turns into a small mist.
2. Mouthpiece- it helps to Releases the high-speed mist for inhalation.
3. Metering Valve -it helps to regulate the precise dose would be released.
4. Liquid Formulation- it includes the propellant and medication.

These inhalers are a game-changer for respiratory therapy, making treatment faster, effective, and easy to use

The future of inhalation therapy looks very exciting and revolutionary with several new technologies on the horizon. Nanotechnology could make drug delivery more targeted more exact and accurate for desired pharmacological activity, improving effectiveness while reducing side effects. Smart inhalers connected to apps may soon allow real-time monitoring and personalized treatment, helping patients adhere to their medication better. Inhalers might also be used for advanced treatments like biologics, gene therapies, and even vaccines.

3D printing could create customised inhalers according to requirements of each individual while eco-friendly propellants will make inhalers safer for the environment. Artificial intelligence may analyse how patients use their inhalers, predict flare-ups, and suggest timely interventions. Dry powder inhalers (DPIs) are expected to become more accurate and stable, while new nebulizers—like ultrasonic and vibrating mesh types—promise more precise and efficient drug delivery.

Modification in nebuliser

New inhaler designs focus on convenience , patient compliance, breath actuation, dose tracking, and better drug deposition at desired site.

Particle properties such as size, density, charge, hygroscopicity are affect on stability and lung targeting. Nanoparticles posses more stability compared to microsuspensions.

Dry Powder Inhalers (DPIs) and pressurized Metered Dose Inhalers (pMDIs) are main devices; DPIs are propellant-free and more patient-friendly.

III. APPLICATIONS

1) Current applications include nebulized mRNA delivery for protein formation in lung cells, where nanoformulations are administered by inhalation, demonstrating efficient cellular uptake, protein expression, and reduced toxicity in preclinical studies.[12]

2) These devices transform liquid medicines, including innovative carriers such as nanoparticles, liposomes, and gene vectors, into an inhalable aerosol so that medicines can reach deep into the lungs.[13]

IV. FUTURE SCOPE

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V. CONCLUSION

nebulizers continue to play a vital role in the management of respiratory diseases, bridging traditional inhalation methods with futuristic healthcare technologies. Their ongoing evolution promises a future where respiratory therapy is more accessible, intelligent, and effective for patients worldwide.

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