Jet, Ultrasonic, and Mesh Nebulisers: An Evaluation of Nebulisers for Better Clinical Outcomes **(1)**

Nebulisers have been commonly used to deliver aerosolised medications in the treatment of patients with pulmonary diseases for over 50 years. They are the aerosol device of choice when patients cannot coordinate inhalation and actuation needed for the use of the pressurized metered-dose inhalers (pMDIs) or if systemic treatments (IV, IM, Oral) is not desirable. Three types of nebulisers exist: (1) jet nebulisers, (2) ultrasonic nebulisers, and (3) mesh nebulisers.

Nebulisers transform liquid formulations and suspension into medical aerosol. In the past few years, there have been advances in the development of new nebulisers that hold the promise to improve aerosol drug delivery to patients with pulmonary diseases. Nebulisers are divided into three categories: (1) jet nebulisers, (2) ultrasonic nebulisers, and (3) vibrating mesh nebulisers. While jet nebulisers are commonly used for the treatment of patients with pulmonary diseases, they are bulky and require a power source. Due to aerosolised droplets and solvent vapour that saturates the outgoing air, jet nebulisers cool the drug solution in the nebuliser and increase solute concentration in the residual volume. An increase in residual volume reduces the amount of drug or solution leaving the nebuliser system. Although ultrasonic nebulisers are more efficient and compact than jet nebulisers, they cannot be used to deliver proteins or suspensions (Flixotide, Budesonide, etc.). With the development of mesh nebulisers that use lower-frequency waves, heating issues that denature proteins during aerosol therapy are eliminated. Also, it has been shown that mesh nebulisers are suitable for delivery of suspensions (Flixotide, Budesonide, etc.), liposomes, and nucleic acids.

(1) JET NEBULISERS:

Traditionally, jet nebulisers have been used for the treatment of pulmonary diseases. These nebulisers require 2 to 10 L/min of pressurized air to draw medication up through a capillary tube from the nebulizer reservoir in order to generate a wide range of particle sizes that are blasted into one or more baffles, which take larger particles out of suspension and return them to the reservoir. Jet nebulizers are effective in delivering formulations that cannot be delivered with pressurized metered-dose inhalers (pMDIs). For instance, antibiotics, mucolytics, bronchodilators and corticosteroids are some of the medications that can be delivered via jet nebulizers. On the other hand, jet nebulizers can be difficult to use because of their need for compressed air and additional tubing. Also, several studies have proven their inefficiencies in drug delivery **(2)**.

Jet nebulizers with a corrugated tube (example below) are conventional constant-output nebulizers that generate continuous aerosol during inspiration, expiration, and breath-hold. Although the corrugated tube attached to the jet nebulizer acts as a reservoir, there is still significant drug loss during expiration with this type of nebulizer. Other disadvantages of these nebulizers include limited portability, requirements for compressed air sources for operation, and variability between nebulizers.

Equi-Resp - Jet Nebuliser

(2) Ultrasonic Nebuliser

Ultrasonic nebulisers (example below) incorporate a piezoelectric crystal vibrating at high frequencies (1-3 MHz) in order to produce aerosol. They are divided into two categories (1) large-volume ultrasonic nebulizers and (2) small-volume ultrasonic nebulizers. Whereas large-volume ultrasonic nebulizers are most commonly used to deliver hypertonic saline for sputum induction, small-volume ultrasonic nebulizers are used for delivery of inhaled medications. Ultrasonic nebulizers have many limitations compared to jet nebulizers. For instance, they have large residual volumes, an inability to aerosolise viscous solutions, and degradation of heat-sensitive materials. Therefore, they should not be used with suspensions (Flixotide, Budesonide, etc.) and proteins.


Air-one - Ultrasonic Nebuliser

(3) Vibrating Mesh Nebulisers:

Recent improvements in nebuliser technologies have led to the development of vibrating mesh nebulizers using micropump technology for aerosol production. They force liquid medications through multiple apertures in a mesh or aperture plate in order to generate aerosol. As small and portable nebulizers that are powered by either battery or electricity, they have silent operation, short treatment times, increased output efficiency, and minimal residual volume. Advantages of mesh nebulizers include consistent and improved aerosol generation efficiency, a predominantly fine-particle fraction reaching into the peripheral lung, low residual volume, and the ability to nebulize in low drug volumes. The size of the pore, the aerosol chamber, and the reservoir, as well as the output rate of mesh nebulizers, can be adjusted for different drugs in order to optimize aerosol drug delivery to patients. Mesh nebulizers are more efficient than jet nebulizers and can provide higher drug doses to patients. Although human studies with mesh nebulizers are limited, in vitro studies demonstrated approximately 2-3 times higher lung deposition with mesh nebulisers when compared to jet nebulisers **(3)**. Despite many advantages of these nebulisers, there are challenges associated with mesh nebulizers.


Flexineb – Vibrating Mesh Nebuliser

Table 1. Advantages and disadvantages of different types of nebulizers		
Nebulisers	Advantages	Disadvantages
Jet nebulizers with corrugated tubing	• Cheap • Easy to use • Effective in delivering drugs that cannot be delivered with pMDIs (Pressurised Meter Dose Inhalers	• Inefficient • Difficult to clean • Need compressed aie and additional tubing • Loud
Ultrasonic nebulizers	• Easy to use • More efficient than jet nebulizers	•Large residual volume • Inability to aerosolize viscous solutions • Degradation of heat-sensitive materials
Mesh nebulizers	• Fast, quiet, portable • Easy to use • Self-contained power source • Optimize particle size for specific drugs • More efficient than other nebulizers • Silent in use • Effective in delivering drugs that cannot be delivered with pMDIs (Pressurised Meter Dose Inhalers	• More expensive

References:

1. **Jet, Ultrasonic, and Mesh Nebulizers: An Evaluation of Nebulizers for Better Clinical Outcomes by Arzu Ari, Georgia State University**
2. **Hess D, Fisher D, Williams P, Pooler S, Kacmarek RM. Medication nebulizer performance. Effects of diluent volume, nebulizer flow, and nebulizer brand. Chest 1996; 110: 498-505**
3. **Ari A, Atalay OT, Harwood R, Sheard MM, Aljamhan EA, Fink JB. Influence of nebulizer type, position, and bias flow on aerosol drug delivery in simulated pediatric and adult lung models during mechanical ventilation. Respir Care 2010; 55: 845-51.**

Scintigraphy

Nuclear scintigraphy is a helpful diagnostic modality generally used, in horses, to look at radioisotope uptake in bone. A radiopharmaceutical is injected (or in this case, inhaled) into the horse and the radiation emitted by the animal is captured by external detectors (gamma camera) to create the image. The radiopharmaceutical is attached to a drug that travels to a specific area of the body. When you assess the image from the scan, you want to look at the distribution as well as the concentration of the "uptake" of the radiopharmaceutical. The amount and distribution of the uptake gives you an indication of how that specific organ is functioning.

The below pictures represent nuclear scintigraphy tests carried out at the Hagyard Equine Medical Institue in Lexington, KY for both the Flexineb Equine Nebuliser and the Equi-Resp Jet Nebuliser.

In the left picture (Flexineb Equine Nebuliser) you can see a much concentrated deposition of the nebulised radioactive material in the lower respiratory system compared to that on the left (Equi-Resp Jet Nebuliser). This shows us that you get a greater deposition of nebulised particles in a greater concentration into the lower airways via a mesh nebuliser compared to a jet nebuliser