

# Aerosol therapy: 5 Lessons Learned during Covid-19

**National Association of Medical Device  
Educators & Trainers Meeting**

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# Agenda

- Summary of Vibrating Mesh Technology
- Aerosol Terminology
- Ari and Scott - Lessons Learned About Aerosol Drug Delivery in the Era of COVID-19. Chest July 2021
- Disclosure- Medical Science Liaison at Aerogen Ltd

# Factors affecting aerosol delivery

## Anatomy of the lungs<sup>1</sup>



- Airway geometry
- Branching/narrowing of airways
- Humidity in the lungs
- Clearance mechanisms

## Airflow/aerosol physics



- Inspiratory flow rate<sup>2</sup>
- Aerosol particle size<sup>3</sup>
- Aerosol velocity<sup>3</sup>

## Device<sup>2</sup>



- Type of aerosol device
- Residual volume
- Position of aerosol device in ventilator circuit
- Intermittent/continuous nebulisation

## Patient



- Level of cooperation from the patient (e.g. crying in children)<sup>4,5</sup>
- Patient's age<sup>6</sup>

# Aerosol Science – Particle Deposition

- Particles larger than 10–15  $\mu\text{m}$  are deposited in the nose and mouth; particles that are 5–10  $\mu\text{m}$  in size tend to deposit in the upper airways, while particles sized 1–5  $\mu\text{m}$  have a greater probability of reaching the lower respiratory tract (i.e. from the trachea to the lung periphery<sup>1</sup>.
- Most aerosolised particles for therapeutic purposes are in the range of 2–5  $\mu\text{m}$  and diffusion is the predominant mechanism for lung deposition<sup>2</sup>.
- The optimal technique for aerosolisation is important to achieve distal airway and alveolar deposition<sup>2</sup>.

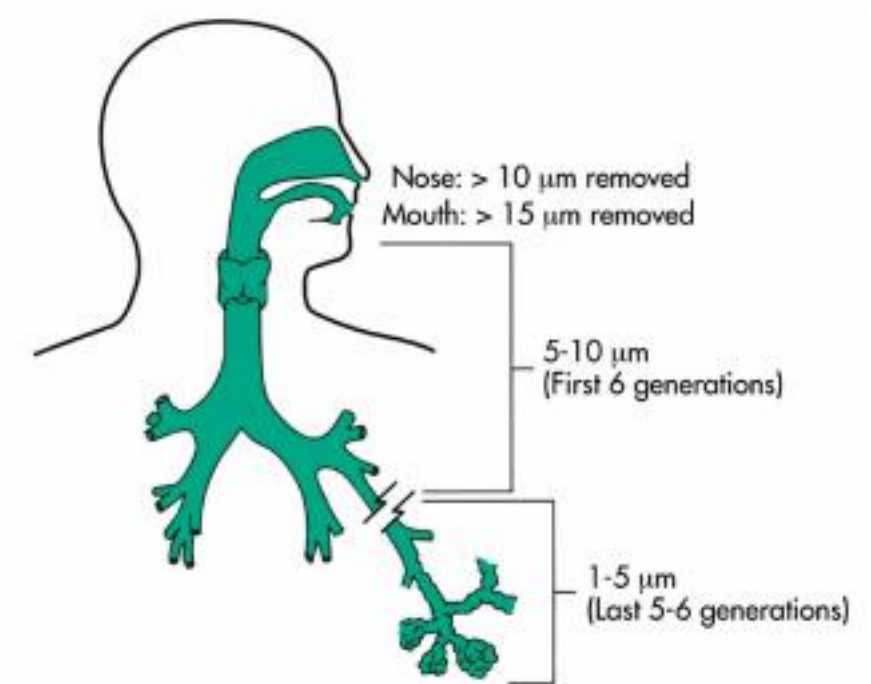


Fig 1. The effect of aerosol particle size on the site of deposition in the airways<sup>3</sup>.

1. McNulty W, Usmani OS. Techniques of assessing small airways dysfunction. *Eur Clin Respir J* 2014; 1. doi:10.3402/ECRJ.V1.25898.

2. Dhanani J, Fraser JF, Chan H-K, Rello J, Cohen J, Roberts JA. Fundamentals of aerosol therapy in critical care. 2016. doi:10.1186/s13054-016-1448-5.

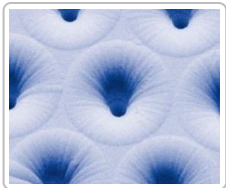
3. Gardenshire, DS. Burnett, D. Strickland, S. Myers T. A Guide To Aerosol Delivery Devices for Respiratory Therapists. <https://www.aarc.org/wp->

# Palladium vibrating mesh (VMN)

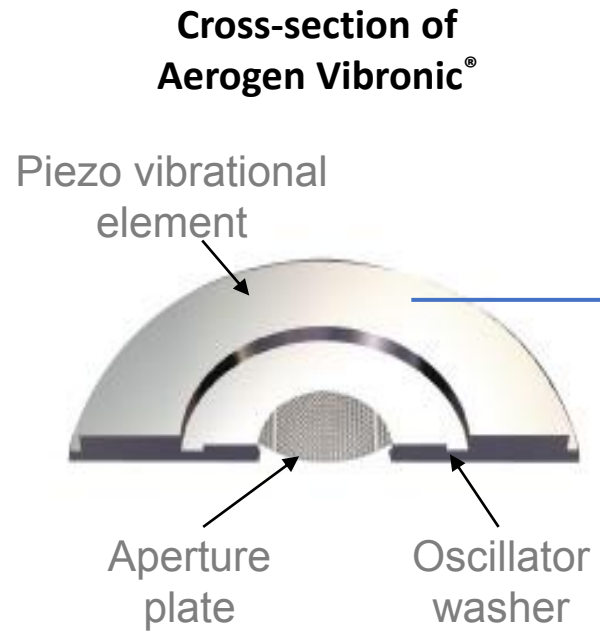


Central aperture plate  
just 5 mm in diameter

Perforated with  
1000 precision  
formed apertures



# VMN aperture plate



Piezo ring vibrates the aperture plate 128,000 times per second

Creates a micro pump that forms a fine particle aerosol of consistently sized droplets



# Aerogen technology in action



# Aerosol Terminology

Term	Definition
<b>Bioaerosol</b>	<ul style="list-style-type: none"><li>Generated by patients during coughing, breathing, talking, or laughing</li></ul>
<b>Medical aerosol</b>	<ul style="list-style-type: none"><li>Generated by aerosol drug delivery devices</li></ul>
<b>Fugitive emissions</b>	<ul style="list-style-type: none"><li>Medical aerosols released from aerosol device during patient expiration</li></ul>



# Lessons Learned about Aerosol drug delivery during the era of Covid

## 1

- **Lesson 1:** The risk of device contamination and viral transmission differs between devices.
- **Lesson 2:** Select an aerosol device based on the patient's clinical status
- **Lesson 3:** Aerosols can be delivered through HFNC
- **Lesson 4:** Interface selection is as important as device selection in COVID-19.
- **Lesson 5:** Reduce exhaled aerosol dispersion to the environment through good infection control and prevention.

# Lesson 1- The risk of device contamination and viral transmission differs between devices.<sup>1</sup>

- While there is no original study comparing different nebulizers on device contamination and viral transmission
- VMNs may be Less prone to device contamination
  - This is because they are separate to the patient interface.
  - Jet nebulisers are open to the circuit
  - Jet nebulizer require gas flow that may increase environmental aerosol
- Run by electricity, no added flow
- Nebulisation is not classified as an AGP<sub>2</sub>

Separate to the patient interface.

## Covid-19 Guidelines

*“Using a mesh nebuliser in ventilated patients allows adding medication without requiring the circuit to be broken for aerosol drug delivery”*

## GOLD Guidelines 2020 update

## Separate to the interface of the circuit: In-line

- Letter to the editor of the *Journal of Critical Care*
- Reported use of **continuous inhalation by Aerogen Solo** in invasively and non-invasively ventilated **COVID-19 patients with COPD and asthma**
- Authors stated that this **closed system** requires minimal staff handling and no circuit opening, thereby reducing workload and increasing safety
- This is the first report of administering bronchodilators **safely and efficiently** to COVID-19 ventilated patients



## Eliminating the risk of inadvertent connection to medical air via a flowmeter

<b>Date of issue:</b>	16 June 2021	<b>Reference no:</b>	NatPSA/2021/003/NHSPS
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This alert is for action by: Acute, specialist, and any other hospitals with piped medical air.

This is a safety critical and complex National Patient Safety Alert. Implementation should be co-ordinated by an executive lead (or equivalent role in organisations without executive boards) and supported by leaders in critical care, emergency, and respiratory medicine and medical device management.

### Explanation of identified safety issue:

Air flowmeters attached to piped medical air outlets are primarily used to drive the administration of nebulised medication; typically for short periods to manage respiratory conditions. Most other uses of piped medical air do not require an air flowmeter.<sup>Note A</sup>

Due to the proximity of the piped medical air and oxygen outlets at the bedside, and the similarity in design of flowmeters, there is a significant risk when using air flowmeters that patients may be inadvertently connected to medical air instead of oxygen.

A previous alert<sup>1</sup> and additional communications<sup>2</sup> have sought to minimise the use of air flowmeters by encouraging their replacement with compressor or ultrasonic nebulisers, alongside additional risk reduction methods if air flowmeters remained in use. A recent survey of Medical Device Safety Officers indicated that many hospitals no longer use air flowmeters and others are part

### Actions required

#### Actions to be completed by 16 November 2021

1. Purchase sufficient powered nebuliser devices for use across the organisation; to remove the need for medical air to drive nebulisers via a flowmeter.<sup>Note B</sup>
2. Remove the need for air flowmeter use in the delivery of humidified air, by purchasing sufficient devices that use ambient air.
3. Review any niche uses of air flowmeters and replace with

## Powered By Electricity

## National Patient Safety Alert

- Flowmeters from medical Air and Medical Oxygen Look similar
- Eliminate Risk:
- Change to powered nebulisers by 16<sup>th</sup> Nov 2021

## Not an Aerosol Generating Procedure.- Nebulisers are not AGPs

Body	Date	Title	Guidance	AGP
<b>World Health Organisation</b>	27 <sup>th</sup> May 2020	Clinical management of COVID-19 (Interim guidance)	Insufficient evidence to classify nebuliser therapy as an AGP that is associated with transmission of COVID-19 <sup>1</sup>	No
<b>Public Health England</b>	20 <sup>th</sup> October 2020	COVID-19 infection prevention and control guidance: aerosol generating procedures	During nebulisation, the aerosol derives from a non-patient source and does not carry patient-derived viral particles <sup>2</sup>	No
<b>British Thoracic Society</b>	13 <sup>th</sup> November 2020	COVID-19 information for the respiratory community	Nebulisation is not considered a 'viral' aerosol generating procedure <sup>3</sup>	No
<b>National Institute for Health and Care Excellence (NICE)</b>	9 <sup>th</sup> April 2020	COVID-19 rapid guideline: community-based care of patients with COPD	Aerosols that come from the nebuliser chamber will not carry virus particles from the patient <sup>4</sup>	No

1. [WHO- Therapeutics and COVID-19: living guideline \(who.int\)](https://www.who.int/publications/m/item/therapeutics-and-covid-19-living-guideline)

2. COVID-19 infection prevention and control guidance: aerosol generating procedures - GOV.UK.

3. COVID-19: information for the respiratory community | British Thoracic Society | Better lung health for all.

4. Overview | COVID-19 rapid guideline: community-based care of patients with chronic obstructive pulmonary disease (COPD) | Guidance | NICE.

## Lesson 2 - Select an aerosol device based on the patient's clinical status.<sup>1</sup>

- Nebulizers should be used in patients who cannot perform the optimum breathing technique required by inhalers
- Clinicians should use jet nebulizers with a valved T-piece or mesh nebulizers to avoid breaking the circuit for device placement.
- When the drug formulation is unavailable as an inhaler.
- Pressurized metered-dose inhalers directly to the tracheotomy tube will cause cough and airway irritation

# Nebulizers should be used in patients who cannot perform optimal breathing technique

- pMDIs are dependent on Patient technique in Spontaneous breathers and Health Care Practitioner Technique in NIV/ MV. <sup>1</sup>
- Changing medication in a Jet Neb requires opening the circuit and HCP focus and time <sup>2</sup>

1, Gardenshire, DS. Burnett, D. Strickland, S. Myers T. A Guide To Aerosol Delivery Devices for Respiratory Therapists. 2017.

2. Ari, A, Scott, B. Lessons learned about Aerosol drug delivery during the era of covid. Chest. July 2021.



# Changing Medication- FUGITIVE EMISSIONS: Nebuliser Type Influences Both Patient-Derived Bioaerosol Emissions and Ventilation Parameters during Mechanical Ventilation

- JN (Clamped and Unclamped) vs VMT when refilling medication.

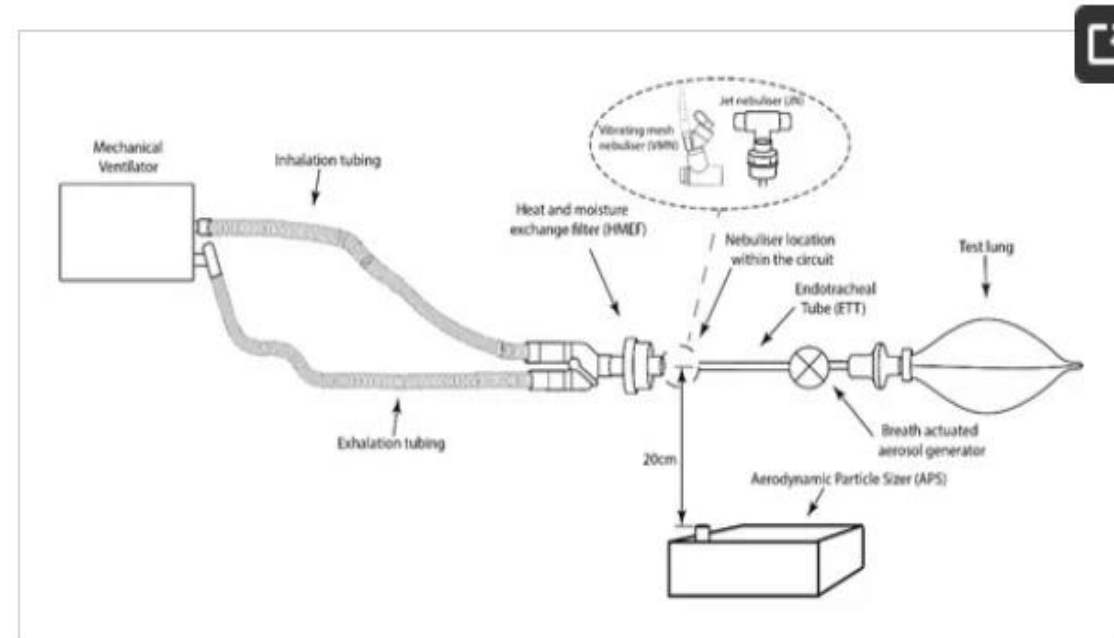
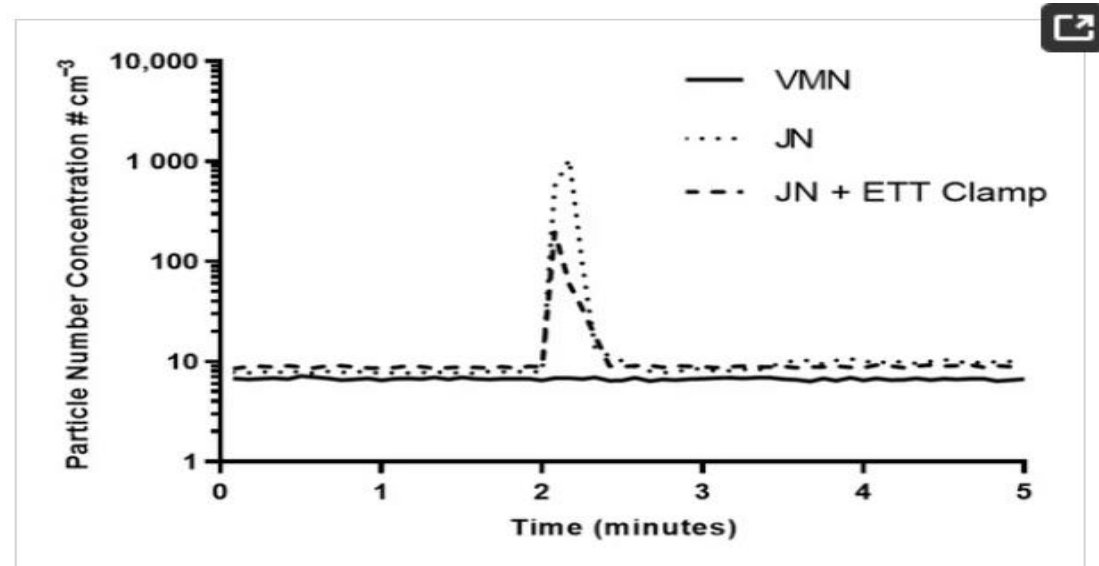


Figure 1. Illustration of experimental setup.

# Changing Medication-Fugitive emissions results

- JN (Clamped and Unclamped) vs VMN when refilling nebulizer.
- VMN- Drug refill with the VMN limits the release of patient-derived bioaerosol, as compared with a JN



**Figure 4.** Average particulate number concentrations (PNC) for three runs for each test scenario over a five-minute period. The drug refill process was completed at the 2-minute timepoint.

# When the drug formulation is unavailable as an inhaler

- Ultrasonic nebulisers produce heat during nebulization affecting drug integrity <sup>1</sup>
- Several drugs are not available as MDI formulations <sup>2</sup>

1. Vecellio L. The mesh nebuliser: a recent technical innovation for aerosol delivery. *Breathe* 2006; 2: 252–260.

2. Gardenshire, DS. Burnett, D. Strickland, S. Myers T. A Guide To Aerosol Delivery Devices for Respiratory Therapists. 2017.

# Pressurized metered-dose inhalers directly to the tracheotomy tube will cause cough and airway irritation

- Gaeckle et al. found that coughing increased aerosol emissions 3-fold
- 10 Healthy Volunteer Mechanistic Study- aerosols were measured in a negatively pressurized room
- Measured by an Aerodynamic Particle Sizer
- Coughing caused the most aerosol generation

## Lesson 3 -Aerosols can be delivered through HFNC.<sup>1</sup>

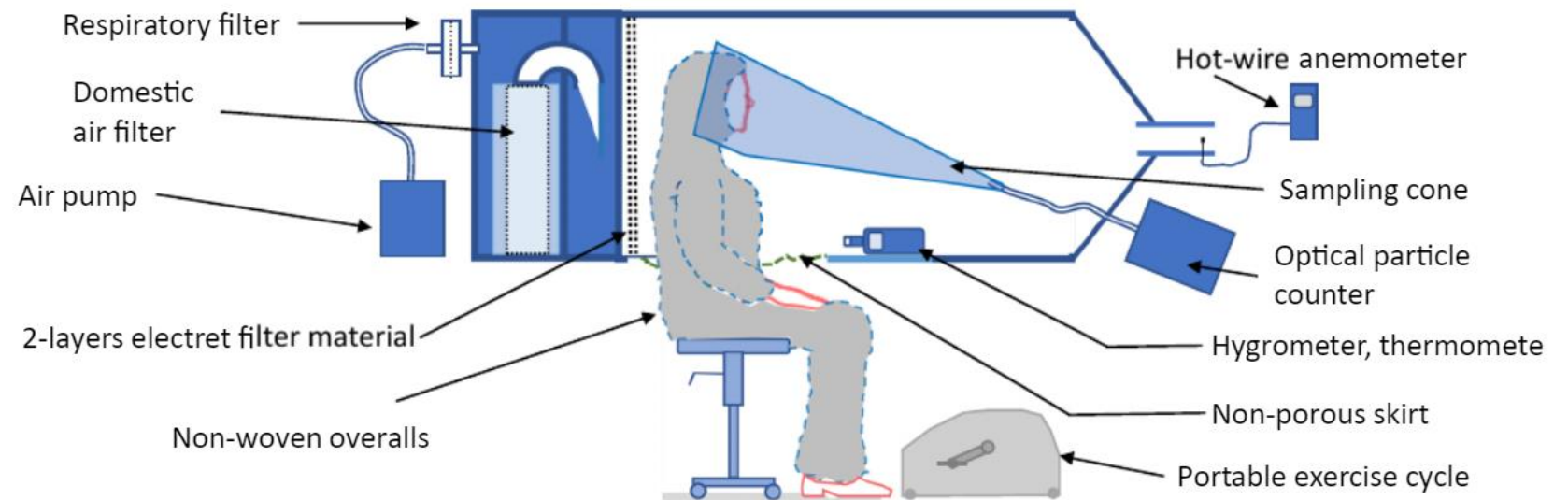
- Concerns remain for exhaled air dispersion and viral transmission with HFNC.
- However, the dispersion distance of exhaled particles with HFNC is less than with Venturi and nonrebreather masks.

# Coughing- Respiratory Support and AGPs

- Dr Nick Wilson and team developed a novel chamber to study emissions and looked at 10 healthy Volunteers
- Expiratory droplet investigation system (EDIS)
- Exertional breathing coughing, reading loudly
- These maneuvers were performed HFNO, NIPPV and without

Wilson et al. | Determinants of aerosol generation

Anaesthesia 2021, 76, 1465-1474

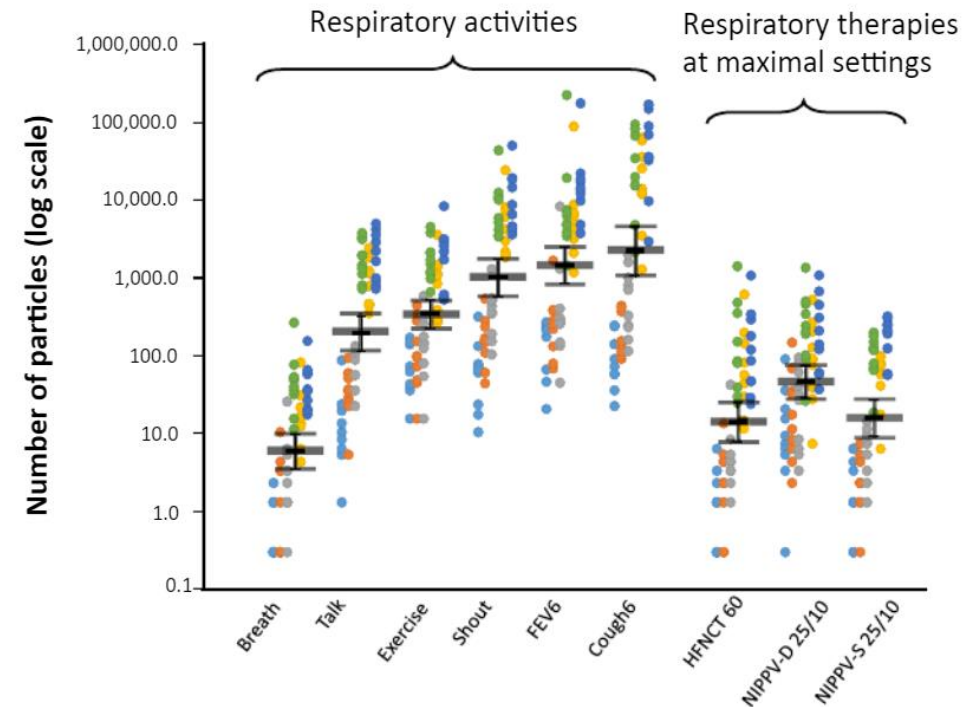


# Respiratory Support and AGPs

- Exertional breathing and coughing - mimic respiratory patterns during illness generate substantially more aerosols than non-invasive respiratory therapies <sup>1</sup>
- Gaeckle et al. found that NIPPV and HFNO did not generate significantly more aerosols <sup>2</sup>

Anaesthesia 2021, 76, 1465-1474

Wilson et al. | Determinants of aerosol generation



## Aerosol delivery during HFNC

# How to deliver aerosolized medications through high flow nasal cannula safely and effectively in the era of COVID-19 and beyond: A narrative review

Arzu Ari, PhD, RRT, PT, CPFT, FAARC, FCCP<sup>1</sup>, Gerald B. Moody, BSRC, RRT-NPS<sup>2</sup>

### *Key recommendations*

- Prefer **mesh nebulisers** over JNs due to their greater **efficiency** during HFNC therapy
- Since mesh nebulizers are operated by electricity, they may be more suitable for HFNC because they **don't add extra gas flow** to the system, unlike JNs
- Place the mesh nebuliser at the **dry side of the humidifier** to improve aerosol delivery through HFNC
- Place a **surgical mask** on the face of the patient using HFNC to minimize exhaled air dispersion and viral transmission



## Lesson 4 –Interface selection is as important as device selection in COVID-19<sup>1</sup>

- use a mouthpiece or T-piece for aerosol delivery to spontaneously breathing or tracheotomized patients, respectively
- surgical mask over HFNC decreases exhaled aerosol dispersion

# Assessments of Fugitive Aerosol Particle Concentrations Generated by Small Volume Nebulizer and Vibrating Mesh Nebulizer

- **Methods:** **9 healthy volunteers** were given treatments of 3mL saline using a **JN** and **VMN** (Aerogen Solo and Ultra) with a
  - mouthpiece
  - mouthpiece with filter
  - mask
  - mask with scavenger
- **Results:**
  - **JN** produced **higher fugitive aerosol concentrations** than VMN
  - Masks generated higher fugitive aerosol concentrations than mouthpiece
  - Adding a **filter to mouthpiece** or a scavenger to mask reduced fugitive aerosol concentrations for both JN and VMN
- **Conclusion:** Fugitive aerosol concentrations were higher with JN than VMN

## Lesson 5- Reduce exhaled aerosol dispersion to the environment through good infection control and prevention.

- Use filters to the expiratory outlet of nebulizers and ventilators
- A closed circuit
- Adhere to airborne precautions, stringently use personal protective equipment, and bundle activities to minimize room entries in the era of COVID-19.

# Aerosol delivery in mechanically ventilated COVID-19 patients

- This review provides **guidance on nebulisation** during the pandemic.

## *Patients receiving ventilatory support*

- VMN should be preferred when treating ventilated patients, but in this case it is necessary to place an additional **filter on the expiratory limb** of the ventilator circuit during nebulisation.
- **Avoid opening the ventilator circuit** to add medication or change nebulisers, because this generates aerosol from condensate that may be infectious
- VMNs generate aerosols via mesh plates that separate the **sealed medication reservoir** from the patient interface
- During nebulisation, the aerosol derives from the fluid in the nebuliser chamber and **does not carry patient-derived viral particles**

# Keep the Line in-tact - A closed circuit

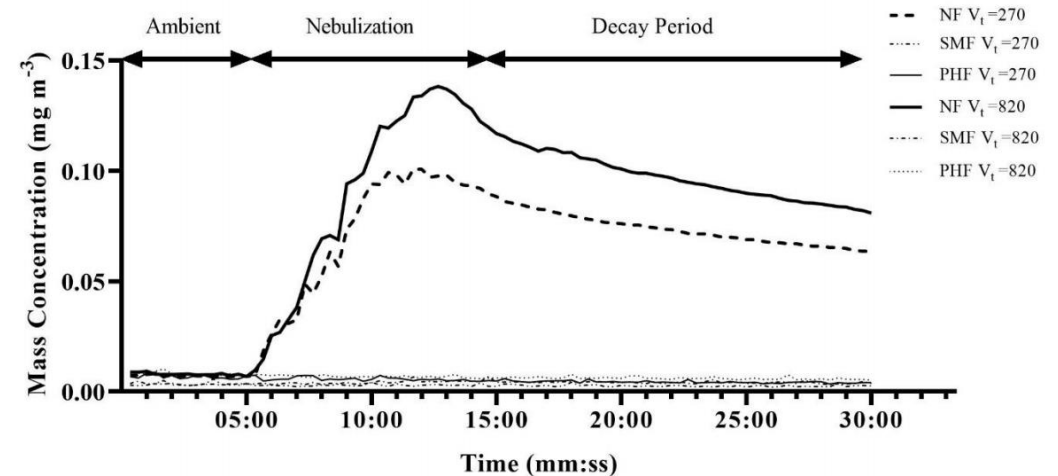
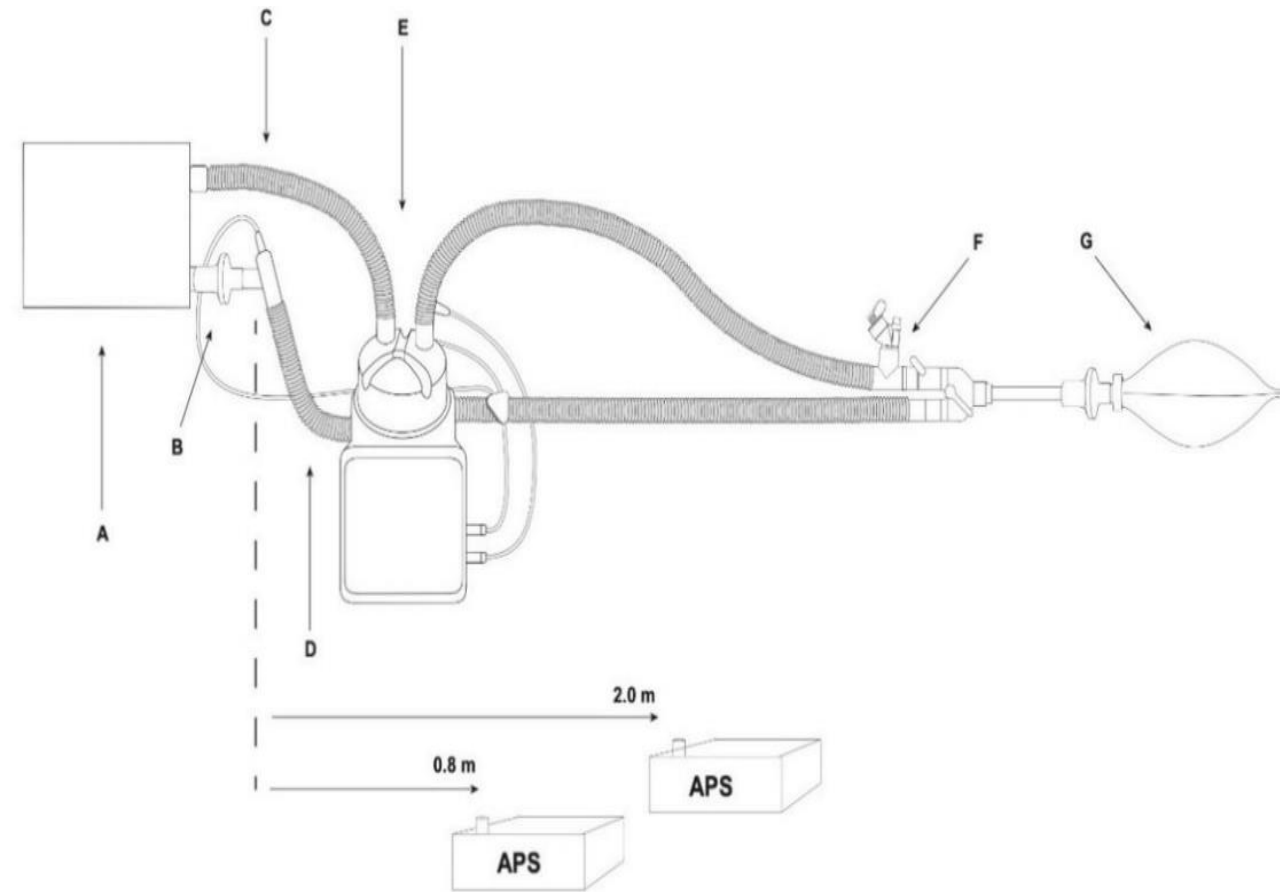
Committee Of Chinese Thoracic Society. - Expert consensus on respiratory therapy related to new coronavirus infection in severe and critical patients

- A Chinese expert consensus on **reducing viral transmission** during respiratory care for patients infected with COVID-19
- For **mechanically ventilated patients COVID-19** patients requiring inhalation therapy, it is recommended to use **a vibrating mesh nebulizer**
- An **additional filter** to be placed at the **expiratory port** of the ventilator during nebulization
- The vibrating mesh nebuliser should be positioned at the **dry side of the humidifier**



# Keep the Line in-tact - A closed circuit

## Fugitive medical aerosol emissions during mechanical ventilation



Average fugitive medical aerosol concentrations at 0.8 m from the ventilator at varying tidal volumes (270 mL and 820 mL), comparing different filters (no filter, single membrane filter and pleated hydrophobic filter).

- An appropriate filtration protocol **mitigates the risk of fugitive medical aerosol emissions** being released when patients undergo aerosol therapy during mechanical ventilation.

# Summary

- **Lesson 1:** The risk of device contamination and viral transmission differs between devices.- Recommend VMN
- **Lesson 2:** Select an aerosol device based on the patient's clinical status-
- **Lesson 3:** Aerosols can be delivered through HFNC
- **Lesson 4:** Interface selection is as important as device selection in COVID-19-
- **Lesson 5:** Reduce exhaled aerosol dispersion to the environment through good infection control and prevention.

Thank you

Questions?

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