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Covid Safety Comparison: Radioaerosol and Xenon Delivery

As the developer and manufacturer of the highly acclaimed Aero/Vent™ and Insta/Vent™ Radioaerosol Delivery Systems, as well as the Xenon/Master® Patient Delivery System, Medi/Nuclear® has extensive experience and expertise in both ultrafine particle aerosol delivery and Xenon delivery. With an emphasis on both performance and safety, all of Medi/Nuclear's products have been designed with the needs of Nuclear Technicians, physicians, and patients in mind. While researchers continue to debate the many challenges presented by the Covid-19 virus, Medi/Nuclear® is pleased to share useful information based on internal and clinical research, as well as product history spanning more than four decades.

Covid-19 Overview

According to the Centers for Disease Control (CDC), research states that the particle size of SARS-CoV-2 is around 0.1 micrometer (µm). However, the virus generally does not travel through the air by itself. These viral particles are human-generated, so the virus is trapped in respiratory droplets and droplet nuclei (dried respiratory droplets) that are larger than an individual virus. Most of the respiratory droplets and particles exhaled during talking, singing, breathing, and coughing are less than 5 µm in size[1]. So how can we protect ourselves from these small particles during a ventilation study? Read on for important points about radioaerosol and Xenon delivery, in regards to Covid safety.

	RADIOAEROSOL	XENON
BREATHING TECHNIQUE	➢ With Medi/Nuclear's Aero/Vent™ and Insta/Vent™ Radioaerosol Delivery Systems, just normal tidal breathing is required, rather than deep breathing or a breath hold, which are likely to invoke coughing in a sick patient. ➢ Not only is normal, tidal breathing more comfortable for a patient, and therefore likely to improve compliance, it also allows the very small particles to be delivered to the alveoli. ➢ Research has shown that when drugs inhaled at a slow inspiratory rate and those at a faster rate are compared, faster inhalation was less effective because more drug impacted in the oropharynx and was lost[2].	➢ As Xenon is a gas, a deep breath with a breath hold is required during dosing. ➢ Observation has shown that asking a sick patient to take a deep breath and hold it will quite often result in a cough, increasing the possibility of dislodging a mouthpiece and releasing fugitive aerosols into the atmosphere[3].
CLEANING/ DISINFECTING	➢ Cleaning and disinfecting Aero/Vent™ and Insta/Vent™ Radioaerosol Delivery Systems is a simple process that may be performed following each patient. ➢ Administration kits can be quickly removed from a shield and are fully disposable, reducing the possibility of cross-contamination.	➢ For maximum protection, Xenon delivery systems must be regularly monitored for changes to system components and connections, and items such as charcoal traps, internal bags and absorbent granules, routinely replaced.

	➢ Lead shield surfaces are non-porous and may be gently wiped down internally and externally with rubbing alcohol or other disinfectant, and then left to air dry.	➢ To minimize possible surface contamination, a system's exterior may be wiped down with appropriate cleaning/disinfecting agents following each patient. However, a system's internal components may not easily be disinfected, if at all. ➢ To minimize the possibility of system contamination, Medi/Nuclear® recommends the use of its #MN2700 Xenon Administration Set with double HEPA filters, a direct dose adapter and an air cushioned face mask.
FILTRATION* **(SEE VIRAL HEPA FILTRATION OVERVIEW BELOW.)**	➢ Aero/Vent™ and Insta/Vent™ radioaerosol administration kits come with a proprietary viral HEPA filter, as standard. ➢ According to the Centers for Disease Control (CDC), by definition, a High Efficiency Particulate Air (HEPA) filter is at least 99.97% efficient at capturing particles 0.3 µm in size. This 0.3 µm particle approximates the most penetrating particle size (MPPS) through the filter. **HEPA filters are even more efficient at capturing particles larger and smaller than the MPPS.** Thus, HEPA filters are no less than 99.97% efficient at capturing human-generated viral particles associated with SARS-CoV-2[1].	➢ Xenon administration sets most often come with a bacterial viral filter. ➢ Bacterial viral filter testing procedures and results vary, and should be considered prior to use. ➢ With a healthy patient, a bacterial viral filter is generally sufficient but with a sick patient a **HEPA filter is strongly recommended**.
PATIENT DOSING	➢ Radioaerosol dosing can be performed in a room other than the scanning room, reducing possible contamination of the camera. ➢ Should a sick patient cough during dosing, the air source may be turned off and dosing resumed when the patient is ready. ➢ After a procedure, before removing a face mask or mouthpiece, have the patient continue breathing room air via the circuit for an additional 20-30 seconds (4-5 breaths). This will maximize the clearance of any remaining activity in the tubing and reduce the possibility of inadvertent contamination to the patient, Nuclear Tech, or room by allowing particles to be captured in a HEPA filter.	➢ Xenon is delivered in the scanning room. Should inadvertent leakage occur from a patient's nose or mouth, the camera and scanning room could be contaminated and require closure for cleaning. ➢ Should a patient cough during administration, Xenon may not be effectively delivered and the study could be lost. A cough during equilibrium or washout would be an interruption but the study would most likely continue. ➢ When there is a high incidence of infectious disease, or a patient's condition is unknown, it is wise to treat all patients as being potentially infected and utilize available safety precautions.

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PATIENT INTERFACE	➢ When Covid-19 is suspected or unknown, a secure, properly fitted face mask with head harness are recommended. The face mask will cover a patient's face and mouth, and allow any coughs to go through the circuit and into the HEPA filter, without contaminating internal shield components. ➢ Merely placing a face mask on a patient's face may not allow the edges to seal securely. To properly apply a face mask, place it on the bridge of the nose and then carefully roll it down toward the chin. ➢ Nose hair can strip particles from aerosol mist making dosing slightly longer. For faster dosing, have a patient breathe through his/her mouth. ➢ If a mouthpiece must be used, Medi/Nuclear's scuba style Safety Shield™ Mouthpiece with protective cap, is suggested. As compared to a straight mouthpiece, the scuba style 1) provides better protection against leakage from the corners of a patient's mouth, 2) is less likely to slip from a patient's mouth, and 3) features bite wings to open the teeth slightly for improved airflow. The cap can be used to catch contaminated saliva during mouthpiece removal and then to cover the mouthpiece for a safer disposal. As always, a properly placed nose clip is required when a mouthpiece is being used.	➢ When Covid-19 is suspected or unknown, a Xenon administration set with air cushioned face mask **and HEPA filter** is recommended. ➢ The face mask will cover a patient's face and mouth, allowing any coughs to go into the HEPA filter, thereby reducing the risk of system contamination. ➢ A HEPA filter will trap most, if not all, exhaled contaminants prior to entering the system. For extra protection, Medi/Nuclear's #MN2700 Xenon Administration Set features double HEPA filters, a direct dose adapter and an air cushioned face mask. ➢ Merely placing a face mask on a patient's face may not allow the edges to seal securely. To properly apply a face mask, place it on the bridge of the nose and then carefully roll it down toward the chin. ➢ A face mask harness is recommended as it will help to secure the face mask, reducing possible contamination from a poorly fitted or loosely held face mask. ➢ Should a mouthpiece be needed, Medi/Nuclear's scuba style Safety Shield™ Mouthpiece with protective cap, is suggested. As compared to a straight mouthpiece, the scuba style provides better protection against leakage from the corners of a patient's mouth, is less likely to slip from a patient's mouth, and features bite wings to open the teeth slightly for improved airflow. The cap can be used to catch contaminated saliva during mouthpiece removal and then to cover the mouthpiece for a safer disposal. As always, a properly placed nose clip is required when a mouthpiece is being used.

SYSTEM DESIGN	➢ Radioaerosol delivery systems are closed systems. A closed system is a system where only energy can be exchanged but not matter. Matter cannot be exchanged in a closed system because matter contains particles which cannot cross the boundary of the system[4]. In the case of ventilation studies, energy would be airflow entering and exiting the system and matter would be particles trapped inside the administration kit by a HEPA filter. ➢ One of the biggest and most easily attained benefits of implementing a closed system, whether in research, pilot or large scale, is in reducing the risk of contamination by viruses or other adventitious agents[5].	➢ A Xenon delivery system is an open system. An open system can be defined as a system which can exchange both matter and/or energy with the surrounding[4]. In the case of ventilation studies, energy would be airflow entering and then exiting the system but matter, being particles, may also exit the system if it is not properly maintained and operated. ➢ Open systems naturally provide more opportunities for contamination because the process is open to the room environment and handling by operators[5]. ➢ However, the risk of particles exiting the system can be minimized with proper preventative maintenance and enhanced dosing procedures, such as the use of a HEPA filter during patient dosing.
VENTILATOR DEPENDENT PATIENTS	➢ Imaging may be performed on mechanically ventilated patients using Medi/Nuclear's special administration kits for ventilator dependent patients. Kits attach to standard 15mm endotracheal or tracheotomy tubes and as always, feature HEPA filtration.	➢ Xenon is generally not used to image mechanically ventilated patients.
***VIRAL HEPA FILTER OVERVIEW**	➢ Viruses that are involved in transmission of infection are not generally 'naked'. They are expelled from the human body in droplets containing water, salt, protein and other components of respiratory secretions. Salivary and mucous droplets are much larger than the virus, and it is the overall size that determines how the droplets and aerosols move and are captured by mask and filter fibers. Exhaled salivary/mucous droplets start from approximately 0.5 µm in size[6]. ➢ To understand the value of HEPA filters, a brief HEPA filter lesson is generally required. HEPA is an acronym which stands for High Efficiency Particulate Air**. HEPA filters provide a very high level of filtration efficiency for the smallest, as well as the largest particulate contaminants.** As defined by the Institute of Environmental Sciences and Technology, IEST-RP-CC001.3 and MIL-STD-282 Method 102.9.1, a HEPA filter must capture a minimum of 99.97% of contaminants at 0.3 µm in size. This 0.3 µm benchmark is used in efficiency ratings, because it approximates the most difficult particle size for a filter to capture. **HEPA filters are even more efficient in removing particles that are smaller than 0.3 µm and larger than 0.3 µm.** The fact that a HEPA filter's removal efficiency increases as particle size decreases below 0.3 µm is counter-intuitive. However, this is a proven and accepted fact[7]. ➢ HEPA filters remove particles from an air stream using 4 main processes. 1) The largest particles are strained. Straining accounts for about 1% of the particles captured by a filter. 2) Large particles are captured through impaction. Impaction accounts for another 1% of particles picked up by a filter. 3) Mid-size particles are removed through interception, which accounts for roughly 30-40% of the total particles removed from the air by a filter.	

4) The smallest particles are diffused. Diffusion accounts for the majority of particles removed by a filter[8].

- HEPA filters do not simply strain out particles, but physically remove particles from the air stream using a combination of impaction and interception (where faster moving particles hit and stick to fibers via a direct collision or a glancing blow), diffusion (where slower moving particles touch and stick to the fibers), and electrostatic forces (where oppositely charged particles and fibers adhere to each other). Together, these create a 'dynamic collision trap' as particles pass through the network of air channels between fibers at various speeds. Particles smaller than 0.3 µm are captured with greater efficiency because their Brownian motion (allowing diffusion at an atomic level) causes them to collide with fibers in the filter at a high rate[6].
- Very simply put, the tiny mass of particles less than 0.3 µm means they do not fly straight. Instead, they are bounced off other molecules as they collide with them and thus move in completely random patterns. As a result, they hit the filter fibers and then remain stuck in them. This is the principle of Brownian movement[9].
- Particles larger than this limiting diameter (0.3 µm) are removed efficiently through impaction and interception[6].
- All of Medi/Nuclear's radioaerosol administration sets, as well as several of its Xenon administration sets, utilize proprietary viral HEPA filters. HEPA filter testing was performed by Nelson Laboratories, which provides a more severe challenge to most filtration devices than would be expected in normal use[10]. As required, results confirmed at least 99.97% trapping efficiency of particles 0.3 µm in size.
- HEPA filter testing performed in Medi/Nuclear's aerosol lab has shown 99.9825% trapping efficiency, under normal patient use. As Medi/Nuclear's Insta/Vent™ and Aero/Vent™ radioaerosol delivery systems produce ultrafine particles with MMAD of 0.28 µm, meaning half of the particles are larger than this and half are smaller, they are very effectively captured, as seen by the high rate for trapping efficiency.
- According to research performed by the National Aeronautics and Space Administration (NASA), when used alone, HEPA-rated media provides superior performance for removing virtually 100% of particulates[11]. Those doubting this should keep in mind that very few, if any, particles will pass through a HEPA filter but should they, not every exhaled particle will be virus laden or carry a significant viral load. Should concerns remain, a second HEPA filter may be added.

SUPPLEMENTARY PRODUCT INFORMATION

- Because particles remain in the lungs, particles have the advantage of allowing for imaging in multiple projections which can be more easily compared with the perfusion images[12.]
- 140-keV gamma photon provides high quality images[13].
- Aero/Vent™ and Insta/Vent™ Radioaerosol Delivery Systems have been used with SPECT for well over a decade. In addition to DTPA, ventilation studies are performed with PYP, MIBI, MDP, and Sulphur Colloid with a physician's order.
- Aero/Vent™ and Insta/Vent™ systems produce ultrafine particles with MMAD of 0.28µm, most being nanosized, allowing significant alveolar deposition for high-quality images.
- Xenon allows for the assessment of all phases of regional ventilation: instantaneous (single breath), wash-in (equilibrium), and wash-out[12].
- The physical half-life of 5.3 days makes ^{133}Xe easy to keep and supply[14].

	➢ Aero/Vent™ and Insta/Vent™ systems with unidirectional airflow support shallow breathers by 1) providing rapid dosing (less than 2 minutes with select systems), 2) virtually eliminating breathing resistance, 3) maintaining the size of ultrafine particles until inhalation, and 4) allowing each breath to be fully medicated. ➢ Radioaerosol equipment costs and required maintenance are minimal when compared to Xenon delivery systems and Technegas.

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