

Heated Expiratory Filtration: Lessons from the SARS Experience

RJ Thiessen, RRT

Royal Columbian Hospital, New Westminster, BC; Vancouver General Hospital, Vancouver, BC

“Although no one did foresee and perhaps no one could foresee the unique convergence of factors that made SARS a perfect storm, we know now that new microbial threats like SARS have happened and can happen again. However, there is no longer any excuse for governments and hospitals to be caught off guard and no longer any excuse for health workers not to have available the maximum level of protection through appropriate equipment and training.”¹

In early March 2003, shortly after realizing that our ICU in Vancouver, British Columbia, Canada was housing the first ventilated SARS patient in North America, we took it upon ourselves to ensure that the filters we were using were adequate for the task. Despite countless articles and reams of data, the information returning from filter manufacturers and distributors wasn't adding up. Evaluating the medical literature on the subject did little to clear up these muddy waters. In fact, our SARS patient was extubated and discharged after more than two months of ventilation in the ICU, and there was still more contradiction than consensus in the available medical literature on filtration. It was roughly this time when a textbook of aerosol technology² put this tiny world of microparticles into crystal clear perspective. It became apparent that “industry” had figured out basically everything there was to know about filtration over about 50 years of scientific study, while healthcare seemed to be in the relatively early stages of trying to reinvent that same wheel. A recent chapter in *Respiratory Care Clinics of North America* lays out the theory behind gas filtration, the concept of Most Penetrating Particle Size, and discusses the flaws with the current practice of evaluating filter performance using microorganisms.³ Another chapter in the same issue of *RCCNA* focuses on the impact SARS had on filter standards in Canada, and discusses “containment” strategies and issues for airborne or highly pathogenic respiratory pathogens.⁴ However, neither article explains reasons that British Columbia's experience with SARS (3 imported cases, 1 secondary spread) was so different from that of Ontario (2 imported cases, 245 secondary spread).

The quick answer, it would seem, is that BC had better luck. BC's index case presented to Vancouver General Hospital's emergency department with undiagnosed fever, respiratory infection, and recent travel history, prompting immediate isolation of the

patient by an alert triage nurse. Fortunately, the patient had not been in contact with any family, friends, or even a doctor's office since onset of symptoms. In contrast, Ontario's first imported case died at home after infecting several family members, one of which presented to a Greater Toronto emergency department with fever, undiagnosed respiratory infection, but no travel history. He subsequently started the spread of SARS through the Ontario public healthcare system.

However, it is my belief there is more to the differences in early management of SARS between the provinces, especially when containment strategies are evaluated. In Ontario the index patient was admitted alongside the emergency department's general population with no mask, and when respiratory failure became imminent, he was non-invasively ventilated using a single-limb system (expired gases are vented through an intentional leak in the inspiratory circuit) which, due to design, cannot be filtered. In contrast, the BC index patient's infection was flagged as “potentially airborne”, so he was given a mask to wear, placed in isolation, and when respiratory failure became imminent, he was intubated and ventilated. Here is where I believe BC's second stroke of luck appeared. At the time, Vancouver Hospital had no infection control policy regarding filtration on ventilators, and only slightly more than half the fleet of intensive care ventilators had built in filtration. By a stroke of good fortune,



DX/800 Expiratory Filter

the respiratory therapist decided to use a Puritan Bennett 840 ventilator. For the next 63 days, the patient was ventilated using, although we didn't know it at the time, the highest rated filtration level recognized by NIOSH. Both the inspiratory and expiratory filters met NIOSH N100 criteria (>99.97% removal of the most difficult particles to capture); additionally, the expiratory filter was a low-resistance, heated, N100 equivalent expiratory filter. The benefit of this design is that virtually 100% containment is provided as long as there are no breaks in the ventilator circuit. With such heated expiratory filters, routine breaks in the ventilator circuit to change filters are not required. In contrast, both heat moisture

exchanging filters (HMEFs) and non-heated expiratory filters require relatively frequent routine changes necessitating breaks in containment, ultimately leading to increased likelihood of exposure to health care workers. The difference in these practices is not based on filtration capabilities between heated and non-heated filters, as there is typically little or no deterioration in filtration performance over time even for non-heated filters.⁵ The main enemy of a non-heated filter or HMEF is condensation of water on the filter media itself. Accumulated condensation from exhaled breath or active heated humidity systems increases the resistance of non-heated filters and HMEFs at such a degree that most manufacturers recommend replacement at least every 24 hours, or earlier if visibly wet, soiled, or contaminated. Every single break in the ventilator circuit should realistically be looked upon as the same "high risk" procedure as intubation or bronchoscopy, and should be avoided as much as possible. While there is no randomized controlled study comparing the systems, it is logical that "N100 equivalent" heated expiratory filters, especially when used in conjunction with heated inspiratory and expiratory tubings (to minimize water buildup in circuit), provide the highest level of containment of respiratory pathogens possible today.

We are rapidly approaching 4 years since Ontario's relatively small outbreak of 247 SARS cases, of which a devastating 43% were healthcare workers and the overall mortality rate was 17%. In that amount of time, especially in light of avian influenza "pandemic preparedness", it may have been expected that much would have changed in regulation or standards surrounding filtration of exhaled gases in healthcare. However, to my knowledge, this is not the case. Individual facilities are left to set up their own containment strategies, and there is still a wealth of misleading information presented by manufacturers, distributors, and medical literature on filtration performance and applications. Respiratory Therapy departments within several health regions in Canada, including the Vancouver Coastal Health Authority and the Fraser Health Authority, have mandated that heated N100 equivalent expiratory filters are mandatory for any new critical care ventilator purchases, and we strongly encourage others to follow suit. Filtration of exhaled gases must be addressed by the governing bodies of healthcare worldwide to ensure the tools are available at the bedside to protect healthcare workers

and public alike against respiratory pathogens, from individual cases of tuberculosis to worldwide spread of novel viruses. All devices used in acute settings for ventilatory support should utilize N100 equivalent heated expiratory filters. Filter manufacturers should be mandated to label all filters sold in healthcare with the equivalent N95, N99, or N100 rating such as we are used to with N95 respirators. Misleading Bacterial Filtration Efficiency and Viral Filtration Efficiency data should be discouraged based on its risk to the public by falsely increasing the sense of security surrounding filtration. Most of all, these changes need to be initiated with some urgency as manufacturers will need time to implement the required changes.

*"The preferred and most effective means of protecting workers is to prevent hazards entering their breathing zone in the first place."*⁶

"One of the key lessons of SARS is the importance of the precautionary principle that reasonable steps to reduce risk should not await scientific certainty... 'Where there is reasonable evidence of an impending threat to public health, it is inappropriate to require proof of causation beyond a reasonable doubt before taking steps to avert the threat'."^{1,7}

References

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**Puritan
Bennett**

4280 Hacienda Drive
Pleasanton, CA 94588
Tel 925.463.4000
Toll Free 1.800.635.5267
www.puritanbennett.com

Tyco Healthcare UK LTD.
154 Fareham Road
Gosport, UK PO13 0AS
Tel +44.1329.224000