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Filtration Efficiency of Pall Breathing Circuit Filters for Human Influenza A (H1N1) Virus

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Introduction

Influenza is caused by viruses of the Orthomyxoviridae family. These viruses cause annual epidemics with tens of thousands of patients dying. Influenza is also associated with recurring pandemic outbreaks which have caused millions of deaths in the past. International and national health authorities assume that nowadays an influenza pandemic would have a devastating socio-economic impact globally, if it hit modern societies that are unprepared. Influenza is transmitted from person to person via virus laden respiratory droplets that are generated particularly when infected persons cough or sneeze and in the exhaled breath of ventilated patients.[1,2,3,4]

The 2009 Influenza pandemic caused by Influenza A (H1N1) virus of swine origin, heightened awareness within both healthcare and public sectors to the possible risks from Influenza and the modes of transmission and led to the query from health care professionals as to whether the Pall Breathing System filters protect against the spread of virus from an infected patient into the breathing system, and in turn, via the ventilator into the ambient air of the hospital.

Pall Breathing Circuit Filters have previously been tested with a variety of clinically relevant bacteria (including: Mycobacterium tuberculosis[5], Pseudomonas aeruginosa[6], Bacillus subtilis[7] and Staphylococcus aureus[8]) and viruses (including, Human Immunodeficiency Virus[9] and Hepatitis C Virus[10] and additionally with aerosolised bacterial (Brevundimonas diminuta[11]) and viral (MS-2 bacteriophage[11]) organisms that represent gold standards for exclusion based on size. Although the date from this testing suggested the breathing circuit filters would act as a barrier to Influenza A the specificity of the question from health-care professionals highlighted the requirement for testing with Influenza Virus itself.

This study, therefore, tested the filtration efficiency of three different Pall Breathing Circuit Filters using a monodispersed aerosol of human influenza A (H1N1) virus. A ratio of the upstream initial viral challenge to downstream residual infectious virus post the filter was used to determine viral efficiency.

Materials and Methods

Pall Ultipor® 25, Ultipor 100 and BB50T Breathing Circuit Filters (BCF) were analysed for their abitlity to retain monodispersed, aerosolised Human Influenza A A/PR/8/34, (H1N1) virus.

The test work was based on the bacterial challenge testing method developed by Duberstein and Howard[11,12] with customisation to viral testing.

The test filter was placed between an upstream evaporator column (fig. 1:4) and a downstream glass impinger (fig. 1:6). The human influenza A (H1N1) aerosol challenge was generated using a six-jet Collision Nebuliser (fig. 1:3) and introduced into the vertical evaporator column (fig. 1:4) to ensure the aerosol challenge was dry and monodispersed.

The H1N1 aerosolized challenge was drawn through the test filter by upstream air pressure in conjunction with a downstream vacuum (fig. 1:15).

The delivery of the virus aerosol was executed over exactly 15 minutes at an air flow rate of 12 L/min.

The aerosol passing through the filter was collected in a glass impinger containing virus collection medium (0.1 x Minimal Essential Medium (MEM) with 0.02% Gelatin).

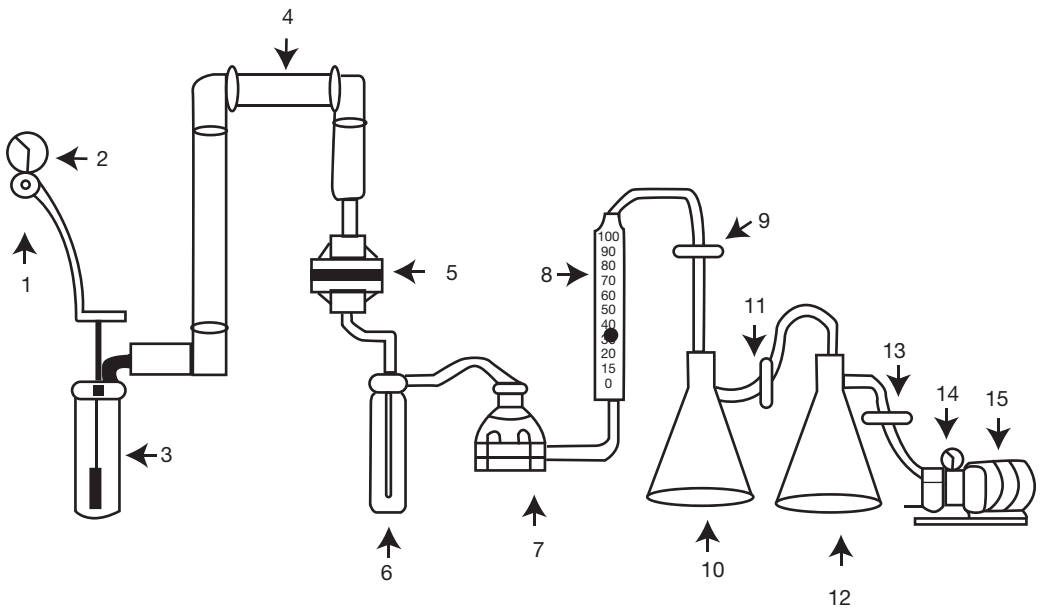
The quantity of infectious virus collected in the impinger was determined using a viral induced cytopathic effect (CPE) assay. Results from the test filters were compared to controls which included a cell viability control (no virus) to ensure the cells were viable and the media sterile and a Virus input control (no filter control) to determine the actual concentration of virus being delivered through the apparatus.

The results were recorded as Initial Viral load and Output Viral Load ($Log_{10}TCID_{50}$) calculated as Titer ($Log_{10}TCID_{50}$/ mL) + Log_{10} [Volume (mL)] the Log reduction was calculated as the Initial Viral load (Log_{10}) - Output Viral load (Log_{10}).

The 50% tissue culture infective dose per mL ($TCID_{50}$/mL) was determined using the Spearman-Karber method[13]. In samples where no virus was detectable a statistical analysis based on Poisson distribution[14] was used to determine the theoretical maximum possible titre for that sample.

Figure 1

Diagrammatic representation of the Viral Filtration Test Apparatus



1. High Pressure Air Source
2. Guage
3. Collison Nebulizer
4. Evaporator Column
5. Test Filter Material
6. Impinger
7. Anderson Impactor
8. Calibrated Flowmeter, L/min
9. Filter #1
10. 4L Vacuum Flask #1
11. Filter #2
12. 4L Vacuum Flask #2
13. Filter #3
14. Vacuum Guage
15. Vacuum Pump

Results

Four replicates of each of the Pall Ultipor 25, Ultipor 100 and BB50T Breathing Circuit Filters (BCF) were analysed. Each filter was tested without pre-conditioning or stressing.

For each test day a cell viability control and a virus stock titre control were included which on both test days showed the cells for the CPE assay were viable, the media sterile and that the virus stock was infectious and had a titre above 7 $Log_{10}TCID_{50}$/mL.

Two replicates of a virus input control were carried out on each day of testing.

The average virus reduction results for each filter type are shown in Table 1.

All three filter types had greater than 99.999% filtration efficiency for H1N1 Virus; 99.9995 for Pall Ultipor 25 and Pall Ultipor 100 Breathing Circuit Filters and 99.9999% for Pall BB50T Breathing Circuit Filters.

Table 1

H1N1 Viral reduction results for Pall Breathing Circuit Filters (results are shown ± 95 % confidence intervals where applicable).

Test Agent	Initial Viral Load* ($Log_{10}TCID_{50}$)	Output Viral Load** ($Log_{10}TCID_{50}$)	Log_{10} Reduction	Virus Filtration Efficiency %
Pall Ultipor 25 Breathing Circuit Filter	7.74 ± 0.27	≤ 2.43	≥ 5.31 ± 0.27	≥ 99.9995
Pall Ultipor 100 Breathing Circuit Filter	7.74 ± 0.27	≤ 2.43	≥ 5.31 ± 0.27	≥ 99.9995
Pall BB50T Breathing Circuit Filter	8.42 ± 0.20	≤ 2.39 ± 0.49	≥ 6.03 ± 0.37	≥ 99.9999

** Results are the average of two replicates*
*** Results are the average of four replicates*

Conclusions

Pall Ultipor 25, Ultipor 100 and BB50T Breathing Circuit Filters were tested for their ability to retain a challenge of aerosolised Influenza A virus (H1N1, A/PR/8/34). The data presented here, using the test apparatus as shown in Figure 1, show that the Pall Ultipor 25 and Ultipor 100 and BB50T Breathing Circuit Filters are able to remove greater than 99.9995%, 99.9995% and 99.9999% of the Influenza A challenge respectively, with log reduction values greater than 5.31, 5.31 and 6.03 respectively.

These results therefore show that the Pall Breathing Circuit Filters can act as a barrier to Influenza A with high efficiency and therefore can be used to protect both healthcare professionals and patients who are breathing the ambient air of the hospital around an infected patient.

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