The influence of mechanical ventilation and portable air cleaners upon aerosol spread in a hospital outpatients clinic

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Background: SARS-CoV-2 global pandemic has highlighted the risk of nosocomial infections of airborne viruses to patient populations around the world. Increased use of mechanical ventilation and portable air cleaners (PACs) have been suggested as methods to mitigate this risk, but the introduction of new air flows to indoor areas can have complex and potentially unforeseen consequences.

Objectives: To investigate the effect of using built-in mechanical ventilation and/or PACs in a typical hospital outpatients' clinic upon the spread of aerosols produced by an aerosol generator.

Methods: We used particle counters to investigate the effect of using built-in mechanical ventilation and/or PACs in a typical hospital outpatients' clinic upon the spread of aerosols produced by an aerosol generator. A variety of scenarios was investigated, examining particle movement to a neighboring room, throughout the whole clinic, and from one room to another at the far side of the clinic.

Results: Whilst both built-in ventilation and PACs may reduce particle migration in some scenarios by up to 96%, use of the same PACs may lead to unexpectedly increased aerosol migration of 29% between neighboring rooms, and use of built-in supply ventilation may increase aerosol migration across the clinic by up to 5.5 times.

Conclusions: These increases are most likely due to the introduction of air flows from the outlets of these devices, providing aerosols with enough momentum to traverse the distance between relatively remote locations or creating recirculation regions that pull aerosols out of one room and push them into another. Accordingly, in order to effectively deploy these useful mitigations to their full potential and not simply displace the risk of nosocomial infection, careful consideration of placement and resultant air flow dynamics is required.

THE INFLUENCE OF MECHANICAL VENTILATION AND PORTABLE AIR CLEANERS ON AEROSOL SPREAD IN A HOSPITAL OUTPATIENT SETTING

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Background

- Nosocomial spread is a significant factor in transmission of respiratory illnesses[1]
- Aerosols (<100 μm) can remain suspended in air, facilitating spread of viral infection[2]
- Built in mechanical ventilation (MV) & portable air cleaners (PACs) could mitigate this[3]
- Effects of ventilation on aerosol migration not fully understood
- Approach to air ventilation historically was to increase number of air changes/ hour[4]
- We have previously shown that air mitigation can be effective in consulting rooms[3]

Aims

- Assess how MV and PACs influence aerosol spread within an outpatient department
- Determine what strategies mitigate or unintentionally worsen aerosol spread
- Explore whether higher air changes per hour (ACH) consistently reduces infection risk

Methods

- Aerosol dispersion experiments in an outpatient clinic, using aerosol generator, VALUATOR/SONNY(**Figure 1**)
- Simulated a human source using aerosolised saline at seated mouth height (1.2m), consistent with patient consultations. Produced aerosalised saline for 15 minutes.
- 2 PACs used
    - P1: Smaller HEPA air cleaner, placed on furniture
    - P2: Larger HEPA air cleaner, placed on floor
- Tested scenarios across
    1. **Full clinic spread:** Aerosols released from consulting room (CR) to entire department, with all doors open.
    2. **Neighbouring rooms:** CR to CR next door/Waiting Room (WR)/Nurses' Station (NS). CR8 to CR7, WRB and NS.
    3. **Cross-clinic movement:** From CR5 to CR1 and NS.
- Particle counters to measure aerosol concentrations (**Figure 2**)
- Conducted in evenings/ weekends with no staff/ patients
- Tested combination of inbuilt MV on & off and PAC placements

Figure 1: VALUATOR/ SONNY

Figure 2: Aerosol particle counter

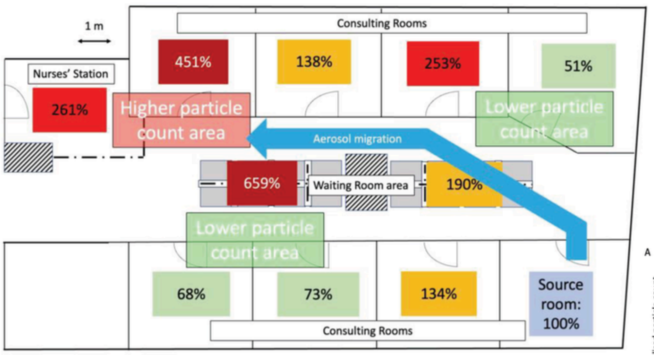

Figure 3: Particle migration across full clinic

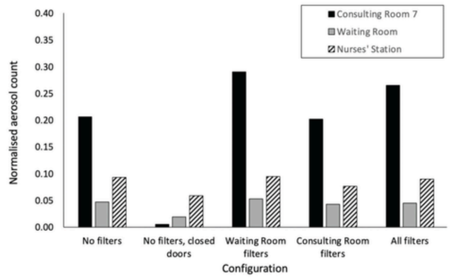

Figure 4: Particle migration to neighbouring room

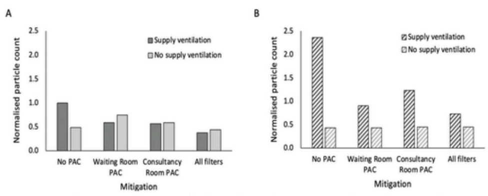

Figure 5: Cross clinic migration. **5A**: Migration to CR1. **5B:** Migration to NS.

Results

- Overall, PACs reduced aerosol counts. However, some configurations produced unanticipated outcomes:

1. **Particle Migration Across the Full Clinic (aerosols from CR5)**
    - Aerosol concentration in CR1, the most distant room, was 184% higher than average across all CRs
    - WR had higher aerosol build up than any other area, at 659% of source room. (**Figure 3**)
2. **Particle Migration to a Neighbouring Room (CR8 to CR7)**
    - Closing doors between rooms reduced aerosol spread
        - Up to 97% reduction when both doors closed
        - 37-59% reduction when only one door closed
    - PAC in CRs alone reduced migration of aerosols by 2-19% (**Figure 4**)
    - PACs in WRs & CRs **increased** aerosol count by 29% in neighbouring CR
3. **Cross-Clinic Particle Movement (all doors closed other than CR1 & CR5)**
    - Turning off inbuilt MV reduced aerosol migration to NS by up to 82%
    - Turning off inbuilt MV had more mixed effect on migration in CR1
        - 52% reduction in aerosols if both MV and PACs absent, vs MV on
        - When PACs added:
            - Aerosol increase of 3-27%, with 27% seen when WR PACs used
    - PACs & MV together generally reduced migration to both NS & CR1
        - 41-69% decrease in aerosol counts vs no mitigation
    - **Figure 5**

Conclusions

- Airflow dynamics in real-world hospital environments are complex and unpredictable.
- PAC effectiveness depends on placement, airflow and interplay with built-in ventilation.
- PACs alone reduced aerosol concentration within rooms, but in some cases, can increase migration elsewhere
- More airflow (via MV or PACs) could propel aerosols to areas further away.
- Highest aerosol buildup sometimes occurred far from the source.

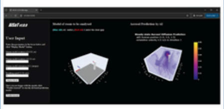

Figure 6: AISAT v1

Future work

- Exhibits need for computational fluid dynamic (CFD) models to accurately determine aerosol spread inside complex clinical environments such as this one
- CFD analysis takes time and high processing requirements
- Team developing an AI software (AISAT, **figure 6**), which can analyse rooms and provide personalised mitigation measures to each room.

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AIR SAFETY PROGRAMME

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