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Confirming estimates of aerosol clearance time

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Confirming estimates of aerosol clearance time

The letter from Cook and Harrop-Griffiths highlights the ongoing concerns regarding the time taken to reduce aerosolised contaminants to safe levels in a positive-pressure ventilated room [1]. They propose a helpful nomenclature (aerosol clearance time; ACT) to clearly identify how many minutes it takes for the ventilation systems in a given space to produce 'n' air exchanges. The US Centers for Disease Control and Prevention (CDC) provides data relating to the number of room air exchanges to the time to clear the space of 99% of aerosols [2]. The authors point out that these data are extrapolated from theoretical principles that can be traced back to a 1973 publication and assume even mixing of that contaminant during the turbulent air exchange inflow and outflow process. We have compared these CDC estimates derived from basic principles to our own data derived from actual patients.

In our recent publication [3], we used single-point air sampling close to the source of aerosol generation during a clinical procedure in an operating theatre environment. We established background particle counts in an operating room with 26.2 air exchanges per hour ($ACT_4 = 9.2$ min). This rate of exchange was validated externally as part of national accreditation requirements in the preceding 6 months. Applying the CDC's assumptions for 99% clearance, approximately 10 min would allow for the necessary 4.7 air exchanges.

We have reviewed our actual clinical data to determine the time from cessation of an aerosol-generating procedure until the particle count from the sampling point returns to at, or near, baseline levels (within $0.1 \text{ particles.cm}^{-3}$) as demonstrated in Figure 1. Where there was sufficient time for count decay after an aerosol-generating procedure to be quantified, the decrease in particle count to near baseline occurred in 4–5 min in three measured episodes and equal to baseline in 5–7 min in

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another three episodes. With our air-exchange rate, 7 min equates to the time for slightly more than three air exchanges. Based on these data, a conservative approach for particle density resulting from localised aerosol-generating procedures to be reduced to background levels would be the time for 4 air exchanges (ACT4) or approximately 10 min. Hence, whilst the CDC data are based on principles published over 50 years ago, it appears that those principles are sound and produce accurate estimates of aerosol clearance times.

It should be noted that real-life aerosol-generating procedures generate a local 'plume' of aerosol which then disperses through the room, hence the concentration of aerosol changes depending on distance from the point of aerosol generation. This differs from the theoretical conditions on which the CDC data are based, which assumes a room whose air has even concentrations of aerosol throughout.

An important consideration to these questions is the air-flow within the room, which is far from simple. The location of the supply and return vents, together with the flow and exchange rates, will influence the turbulent/laminar flow characteristics in the room and, importantly, whether there are any localised eddies, or 'dead zones', formed in the room. Aerosols can enter and exit these isolated dead zones when the dominant flow is disturbed (e.g. a person walking from primary flow into the dead zone), but typically aren't well mixed with the rest of the room. This disconnect from the main flow is important to understand when considering clearance times, which in these zones can be much slower.

It is also important to note that the ACT4 time should start from the end of the last aerosol-generating event and not, for example, from the time of tracheal tube removal. Our data suggest that coughing into a Hudson mask generates large spikes of aerosol and that these coughs should therefore be treated as aerosol-generating events, each of which initiate CT4 minutes of aerosol clearance time.

As part of respiratory management protocols, we believe it is reasonable to apply aerosol clearance times where aerosol-generating procedures occur when there is a high COVID-19 community prevalence or in known COVID-19 positive patients. Based on our data, the CDC estimates of time required to reach 99% aerosol clearance appear accurate. Finally, we recommend that clinicians consider aerosol-generating events after tracheal tube removal, such as patient coughing, as triggers to restart the clock on ACT4 time.

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Figure 1

Aerosol number concentrations (log scale) as measured by a TSI Aerodynamic Particle Spectrometer Sizer (TSI APS 3320, size range 0.37–20 μm) with a cough after extubation of a patient. Dashed lines represent mean concentrations of background periods for overnight (empty theatre) and an occupied theatre (staff and patient in theatre but no aerosol-generating procedure taking place).

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