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UNCERTAINTIES

How should aerosol generating procedures be defined?

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What you need to know

- Opportunistic airborne transmission of aerosols can occur during activities and procedures related to patient care. The mechanisms and quantities of aerosols generated are unknown, but the amount of aerosolisation is likely related to flow rate and volume of air exerted on a patient's mucus-air interface
- The risk of infection from coughing is underappreciated, and the risk from other documented aerosol generating procedures may be overemphasised
- Simulation studies suggest that aerosols exhaled during respiratory treatments are mostly concentrated within 1 metre around the patient, but can be more widely dispersed during coughing or other concomitant respiratory activities

In a healthcare setting, aerosol generating procedures (AGPs) include any medical practice or technique that enables aerosols to be transmitted from one person to another. AGPs have been described as increasing the risk of transmitting viruses that cause severe acute respiratory syndrome (SARS) and covid-19,^{1,2} and precautionary measures are recommended for clinicians who undertake AGPs, to minimise nosocomial infection.

Uncertainty exists over how to define an AGP, and around the levels of risk associated with various procedures.³ Practices that are frequently defined as AGPs include tracheal intubation and extubation, open airway suctioning, sputum induction, bronchoscopy, non-invasive ventilation (NIV), and manual ventilation. Those generally not considered AGPs include ventilator circuit disconnection, oral suctioning and hygiene, transoesophageal echocardiography, and chest tube insertion or removal. Nebuliser treatment, high flow nasal cannula (HFNC), and high frequency jet ventilation are sometimes listed as AGPs.

For the examples that are listed consistently as AGPs, the risk of aerosolisation may be overestimated, and focusing on risk reduction for these procedures underappreciates the risks of aerosolisation in many unlisted patient care activities. Classifying a procedure as an AGP also generates stigma, which may result in unnecessary withholding of treatment and negative impacts on patient care.

Current recommendations on personal protective equipment for healthcare workers is based on the risk of airborne transmission of a particular procedure, but this approach does not fully account

for the high variability of aerosolisation in clinical settings.

How this article was created

We performed a systematic search of the literature in Medline, Embase, the Cochrane CENTRAL register of controlled trials and the Cochrane Database of systematic reviews from January 2000 to April 2021. We used the search terms “exp Coronavirus/”, “exp Coronavirus Infections/”, “Severe Acute Respiratory Syndrome/”, “(covid or SARS or SARS-CoV or pandemic)*” or “severe acute respiratory syndrome coronavirus” or “SARS-CoV-2” or “COVID-19” or “2019-nCoV” or “coronavirus” or “2019 novel coronavirus*” or “wuhan”).ti,ab.” AND “exp Aerosols/”, “exp Personal Protective Equipment/”, “exp Particulate Matter/”, “Lipid Droplets/”, “exp Lipid Droplet Associated Proteins/”, “exp Cross Infection/”, or “aerosol*” or “airborne*” or “droplet*” or “transmit*”, or “health*” and “work*” and “safe*” or “respiratory therap*” or “airway manag*” or “non-invasive ventilation” or “oxygen device*” or “nasal cannula” or “nebulizer”).ti,ab. We screened 4618 articles, and further performed a snowball search from the bibliography of the included articles. Relevant articles were retrieved to form the evidence base for this article.

What is the evidence of uncertainty?

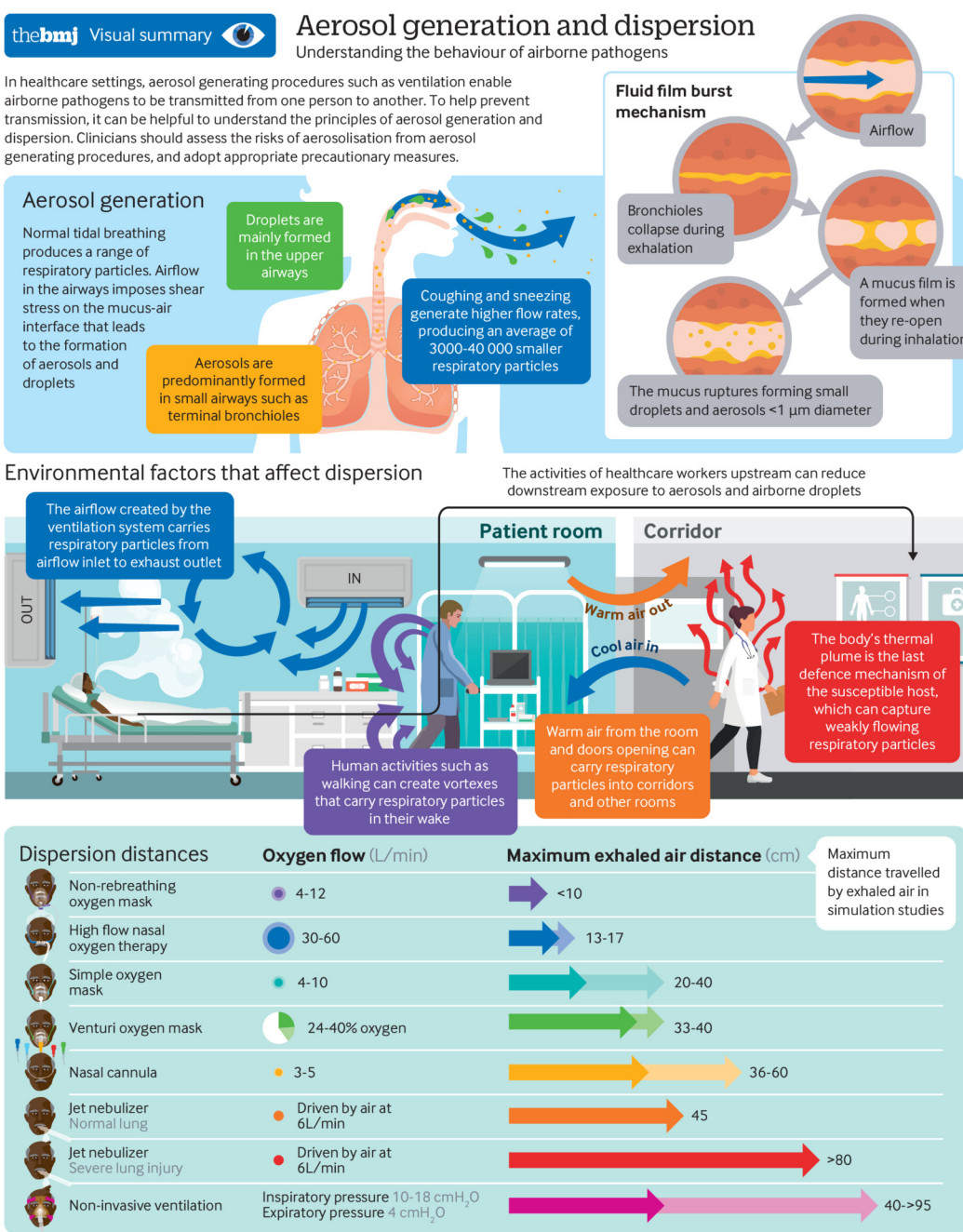
Classification of AGPs is based largely on the reported risks of nosocomial infections during the SARS outbreak of 2003. A systematic review of five case-control studies and five retrospective cohort studies reported an increased risk of superspreading events with tracheal intubation, tracheostomy, non-invasive ventilation, and mask ventilation before tracheal intubation.⁴ However, tracheal suctioning, bronchoscopy, and nebuliser treatment were not found to increase nosocomial infection. The included studies have several limitations that may affect the extent to which they can be used to define and classify AGPs. First, the included studies were retrospective in nature with limited sample size, and were categorised as “very low” certainty of evidence according to the GRADE (Grading of recommendations, assessment, development, and evaluations) framework. Second, awareness of, and compliance with, appropriate infection control measures—which varied considerably between studies—might have significantly mitigated nosocomial infection. Third, no data were provided in the included studies on how aerosols were generated and dispersed, suggesting that aerosol transmission was not fully considered at the time. Recent data indicate that, during the covid-19 pandemic, the death rate of healthcare workers in general practice and psychiatry has been higher than

This is one of a series of occasional articles that highlight areas of practice where management lacks convincing supporting evidence. You can read more about how to prepare and submit an Education article on our Instructions for Authors pages: <https://www.bmj.com/about-bmj/resources-authors/article-types>

in workers in intensive care units who routinely perform the above named high risk AGPs.¹⁰ The current approach of defining and classifying AGPs for covid-19 may have overlooked the biological plausibility of aerosol generation and dispersion of SARS-CoV-2.

Aerosol generation depends on the flow rate of air in the airway. A high flow rate initiates shear stress on the air-mucus interface in the airway and produces aerosols. Knowing air flow rates related to different activities can therefore help us understand the extent of aerosolisation (infographic, [fig 1](#)). Peak flow rates during bag-mask ventilation, suctioning, and HFNC are similar to regular

breathing, and the quantities of aerosols generated would be comparable. By contrast, coughing and sneezing produce flow rates at least 10 times greater,⁵ and are therefore major sources of aerosolisation. Two studies of healthy volunteers^{6 7} found that coughing and shouting generated 10 to 300 times more aerosols than NIV and HFNC. In a recent observational study,⁸ tracheal intubation and extubation produced fewer aerosols than coughing. Overall, these investigations contradict the findings of previous epidemiological studies. As a result, classifications of AGPs vary between professional guidelines, especially in the context of covid-19⁹ (appendix 1).



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Fig 1 | Infographic: Aerosol generation and dispersion

Is ongoing research likely to provide relevant evidence?

We searched the clinicaltrials.gov and ISRCTN registries in March 2022 and identified 18 ongoing studies related to aerosolisation or

AGPs. AERosolisation And Transmission of SARS-CoV-2 in Healthcare Settings (AERATOR) is a prospective cohort study that aims to quantify aerosol generation during and after routine dental, orthopaedic, respiratory, critical care, and ophthalmology surgeries.

Three other clinical studies are evaluating the distribution of aerosolisation during nasogastric tube insertion, use of metered dose inhaler or nebuliser, and procedures related to routine oral care. Other ongoing clinical trials are investigating the use of barrier methods such as aerosol boxes or aerosol reducing mouth guards to minimise dispersion of aerosols in various medical procedures. Additional research questions are shown in [box 1](#). Field studies in hospital isolation rooms and detection of viral particles in air samples by polymerase chain reaction and viral culture during respiratory treatments are of particular interest.

Box 1: Recommendation for further research

- What is the relative importance of aerosol, droplet, contact, and indirect transmission modes in healthcare settings?
- What is the role and extent of airborne transmission in patient care activities or medical procedures?
- What factors determine the risk of aerosolisation during patient care activities or medical procedures? What manoeuvres (eg, to optimise the patient's respiratory condition) can reduce the risk of aerosolisation during AGPs?
- How does aerosol dispersion relate to risk of infection and how does the healthcare setting affect the risk?
- What are the settings and risk factors for superspreading events?
- How can healthcare policy address the risk of airborne transmission from activities related to patient care and medical procedures that carry risks of aerosolisation?

What should we do in the light of the uncertainty?

Given the uncertainty, and the high variability of aerosolisation in clinical settings, healthcare workers should understand the principles of aerosol generation and dispersion (infographic, [fig 1](#)). They should assess the risks of aerosolisation whenever they encounter patients, and adopt appropriate precautionary measures. Frontline healthcare workers may need to undertake substantial training to achieve this. Alternatively, applying universal airborne precaution level of personal protective equipment in all patient encounters may eliminate the uncertainty, but this approach is likely to be constrained by resources.

Coughing and other forms of forced expiration can generate large quantities of aerosols, and these may be further dispersed over long distance if medical devices with a high oxygen flowrate, such as HFNC or jet nebuliser, are used concomitantly. Simulation studies^{11 12} estimate that exhaled air travels up to 1 metre from a patient using an oxygen mask, nasal cannula, HFNC, venturi mask, jet nebuliser, or non-rebreathing masks (infographic). High flow rate, coughing, and NIV increase dispersion in an exponential fashion, whereas a tight-fitting mask, exhalation filter, suction, or expired gas scavenging minimise dispersion. Thus, understanding dispersion characteristics may reduce exposure to respiratory particles. Simulation studies also suggest use of barriers or enclosures to block aerosol dispersion (eg, using an aerosol box during tracheal intubation).¹³ Environmental studies have suggested an association between inefficient ventilation and airborne transmission in SARS and covid-19. Negative pressure isolation rooms can dilute and remove aerosols within the room and should be considered if available.

Education into practice

- Consider the last time you encountered a patient who had covid-19. Which patient care activities or procedures did you undertake that may have increased the risk of aerosol generation?

- What precautionary measures do you perform to minimise aerosol generation and dispersion?

How patients and healthcare workers were involved in the creation of this article

We sought feedback from physicians, residents, nurses, and respiratory therapists when compiling and modifying this manuscript. They made suggestions and edits to improve the clarity and illustration of the article and infographic.

Advisers to this series are Nai Ming Lai, Win Sen Kuan, Paula Riganti, and Juan Franco.

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JC wrote the first draft and takes full responsibility for the work as guarantor. All authors were involved in further drafts and approvals of the final manuscript.

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