Occupational Medicine 2021;**71:**118–120
Advance Access publication on 18 March 2021 doi:10.1093/occmed/kqab033

EDITORIAL

Healthcare workers and protection against inhalable SARS-CoV-2 aerosols

By February 2021 expert groups in several countries had lobbied governments for proper recognition of the risk of aerosol transmission of SARS-CoV-2 and specific strategies to reduce this, including upgrades of respiratory protection (RPE) for healthcare workers (HCWs). This becomes particularly relevant with the emergence of more transmissible strains of SARS-CoV-2 and another wave of disease. Despite overwhelming evidence supporting aerosol transmission of SARS-CoV-2 [1–3], this has not translated into appropriate, consistent policies on RPE for HCWs. Partly, this is attributable to nations and organizations not stockpiling RPE despite the predicted occurrence of an influenza pandemic. A *European Centre for Disease Prevention and Control Technical Report* recommended using filtering facepiece particulate respirators (FFPRs) FFP2 or FFP3, for HCWs assessing suspected cases or managing confirmed COVID-19 cases. Powered air-purifying respirators (PAPR) (with coverall) may afford better protection than a N95 FFPR (and gown) [4], with some advocating these for performing aerosol-generating procedures (AGPs) on COVID-19 patients [5]. National guidelines typically defer to World Health Organization *(WHO) Interim Guidance*: which only recommends FFP2 or N95 or FFP3 for HCWs performing AGPs on COVID-19 patients; and fluid-resistant surgical masks (FRSM) for other HCWs in COVID areas. In the UK, FFP3 (N99) respirators are advocated; where these are not available, FFP2 are considered acceptable since they are comparable to N95: both offer a protection factor of 10 and filter efficiencies of ≥94% (FFP2) and ≥94% (N95) [6]. In December 2020, *WHO Interim Guidance* added that FFPRs may be used by all HCWs providing care to COVID-19 patients ‘if they are widely available and if cost is not an issue’.

Data for HCWs and risk of COVID-19 are limited and reporting schemes are unreliable being vulnerable to under-reporting of cases and occupational attribution. Nonetheless, seroprevalence studies show that hospital patients, visitors and HCWs are at increased risk of infection [7]. During the second wave as many as 19% of COVID patients in English hospitals and a monthly average of 462 daily cases had probable hospital-acquired disease [8]. COVID-19 is more common among HCWs compared to the general population [1,9] and accounts for a greater proportion of sickness absence among doctors compared with other professionally qualified HCWs [10]. HCWs who perform AGPs or work in intensive care units (ICUs), though considered to be at greatest risk of exposure, appear less affected than other HCWs. Compared with the general working population, male HCWs and nurses and nursing auxiliaries and assistants of both sexes demonstrate statistically significant higher rates of COVID-19-related deaths [11]. Seropositivity is lower in COVID-19 departments compared with ICU, and non-COVID departments [12], and lower in ICU staff compared with staff working in housekeeping, emergency departments and general medicine [13,14]. Black and Asian ethnicity is also associated with a significantly increased risk of seropositivity [7,13,14]. In one study, the commonest source of infection was other HCWs (49%) [12]. The lower prevalence of infections among HCWs considered to be at highest risk is likely attributable to better air exchange rates and provision of FFPR and conversely, in other hospital areas, to lower standards of cleaning and disinfection for shared areas such as changing rooms and toilet facilities.

From the outset of the pandemic the public was advised that person-to-person droplet transmission could occur within 2 m; however, public health guidance downplayed the role of aerosol transmission over longer distances. The distinction between aerosol and droplet transmission is a false dichotomy because the respiratory tract produces particles in a continuum of sizes, all of which can transmit SARS-CoV-2 [1,2], and therefore is relevant to social distancing and respiratory protection interventions. While it is difficult to estimate the relative importance of aerosols versus droplets and direct contact [2], there is growing evidence that aerosols are at least as likely to transmit SARS-CoV-2 and cause infection [1,3]. This should not have been a surprise because previous experimental and observational studies have demonstrated aerosol transmission of respiratory viruses, including other coronaviruses and influenza virus [15]. Compared with larger droplets, aerosols are more readily dispersed, travel distances exceeding 2 m, and persist in viable and infectious forms [15,16]. SARS-CoV-2 remains infectious in aerosols for hours [15,16]. Deposited particulates may become resuspended in air when disturbed. Aerosols are spread even further by heating, ventilation and air conditioning (HVAC) systems. SARS-CoV-genes have been detected in room vents and in central ventilation exhaust filters distant from patient areas [2]. Studies have demonstrated extensive environmental contamination of SARS-CoV-2 in hospital settings [2]. Aerosolization and droplet formation occur from breathing and talking as well as coughing and sneezing [16]. During normal speech a SARS-CoV-2-infected person can exhale 10^5–10^7 copies/m^3 at an average respiratory rate of 12 L/min [17]. The emission dose is affected by factors such as activity and disease stage, the highest viral load in throat swabs being at the time of symptom onset [17].

To control such exposures and reduce airborne transmission warrants suitable and sufficient controls. In the *hierarchy of controls* for managing exposure to workplace hazards RPE is less effective than either controlling exposure at source or interrupting transmission by barriers and ventilation. A particular additional concern during this pandemic is the confusion surrounding RPE—FRSM have never previously been, nor should they be, regarded as RPE. Anticipating an influenza pandemic, Britain's Health and Safety Executive Research Report RR619 and the American Occupational Safety and Health Administration Factsheet 3219 stated that FRSM protect against pathogen transmission by splashes or large droplets of body fluids; and are not designed or certified to prevent inhalation of aerosols and viruses. RR619's influenza bioaerosol tests estimated that live viral titres were reduced by at least 100-fold with FFP3 and by around 6-fold with FRSM.

A Cochrane review of randomized trials performed in heterogeneous settings with mostly high or unclear bias reported that wearing FRSM may make little or no difference and that hand-hygiene interventions reduced respiratory infections by 16%, but for influenza-like illness (ILI) and laboratory-confirmed influenza, made little or no difference [18]. Another systematic review similarly concluded that there was no evidence of efficacy for FRSM for HCWs but there was for N95 respirators 'if worn continually during a shift … but not if worn intermittently' [19]. Studies reporting no difference in outcomes might do so because of non-compliance with the intervention [18], lack of continual use, failure to control for infection in unrecognized situations of risk within or outside the workplace when the invention was not used [19] and FFPR efficacy being impaired by improper selection, training, fit, use and removal.

In many countries, employers are legally required to assess exposure risks at work and to do all that is necessary to reduce risks to protect workers and members of the public who might be exposed from harm. Risk assessments should be suitable and sufficient, and in a healthcare setting, should examine and keep under review the hazards, tasks, equipment used and the environment, monitoring results and the hierarchy of control measures in place to control exposures of staff, patients and visitors. For SARS-CoV-2, clinical vulnerability (personal risk factors such as age, ethnicity, gender, health and immune status) must be assessed for each HCW; when included in the assessment, they help determine the protection required. RPE must be appropriate for the specific risks and conditions of use; FFPR with exhalation valves should not be used since exhaled air is not filtered and asymptomatic HCWs can infect co-workers and patients. RPE selection should consider the airborne concentration of the substance related to its workplace/occupational exposure limit (OEL), but biological hazards do not have OELs, so employers follow good practice.

Current public health policies underestimate the role of aerosol transmission and, contrary to the evidence, assume that most infections in HCWs only occur during identified high-risk exposures. The consequences are that HCWs have been infected, mostly subclinically, at work and infect other HCWs. Hospitals have lost capacity to provide care because of staff absence through illness or self-isolation. Some HCWs have died; others will suffer long-term health effects. These avoidable outcomes should be remembered when discussing the costs of FFPR.

The evidence indicates that, in general, HCWs who perform AGPs on COVID-19 patients and who, as a minimum, use N95 FFPR properly are adequately protected against inhalable SARS-CoV-2; albeit employers' risk assessments should consider PAPR to reduce exposure to the lowest levels. In view of the risks (and methods) of aerosol transmission and prevalence of infection among different HCWs, the evidence indicates that HCWs who are not provided with at least N95 FFPR, including HCWs in non-COVID-19 areas, are not adequately protected against inhalable SARS-CoV-2.

Many professional bodies have demonstrated leadership by seeking to influence policy makers to better protect HCWs; others have been conspicuous by their silence. We believe the evidence supports upgrading RPE for all HCWs; whether it be FFP2, FFP3 or PAPR and that government agencies and employers must act to ensure HCWs have access and learn lessons so that HCWs are better protected for future pandemics.

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