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EDITORIAL

Protecting healthcare workers from inhaled SARS-CoV-2 virus

The current Covid-19 emergency presents enormous challenges in the prevention of infection in healthcare workers. TV and media images of these workers show a huge variety of personal protective equipment (PPE) being used, in many cases being worn incorrectly by healthcare workers, compromising the effectiveness. The question is to what extent are these workers at risk of infection from inhaled virus particles and if they are at risk, how should they best be protected?

Every cough and sneeze from an infected person results in a spray of droplets and aerosol containing virus particles being emitted into the air. The subsequent behaviour of that emission depends primarily on size (diameter), with larger droplets either impacting or falling rapidly onto surfaces but smaller aerosol droplets remaining airborne for extended periods [1].

The World Health Organization (WHO) states that Covid-19 infection arises primarily from large droplet spray produced during coughing or sneezing and by direct contact with infected people or with contaminated surfaces [2]. For community transmission this is almost certainly the case, but the position is much less clear for healthcare workers particularly where there is potential exposure from aerosol generating procedures (AGPs).

WHO has stated that aerosol transmission is only possible in a narrow range of AGPs and that respirators are only required in these scenarios. They advise that medical (surgical) masks are sufficient in other healthcare circumstances where Covid-19 patients are present [3].

Our greatest difficulty in recommending effective mitigation is that we have little idea of the actual concentrations of the SARS-CoV-2 virus on surfaces or in the air, and therefore limited understanding of the relative importance of the routes of transmission. The presence or otherwise of an airborne phase, largely discounted by WHO except for a few specific scenarios, has important implications for a mitigation strategy, but it is unclear to what extent the airborne viral load adds to infection risk.

So it is difficult to decide when to advise workers to just wash their hands and social distance and when to use more stringent, in particular respiratory controls. What is appropriate in a ward of Covid-19 patients or for supermarket workers in close contact with the public? How do we assess the risk in these situations and the relative importance of the different virus transmission routes?

In Wuhan, Liu and colleagues [4] investigated airborne SARS-CoV-2 virus in hospitals with Covid-19 patients and public spaces. The four clinical areas investigated had detectable concentrations of the virus, although not the intensive care unit (ICU) which the authors attributed to the high general ventilation rates in these rooms (virus deposition on surfaces was detected in the ICU). The highest concentrations were found in medical staff changing rooms, up to 40 copies m^{-3}, and it was suggested this may have been due to resuspension of virus-laden particles from staff protective clothing while they were being removed. About a third of the samples from public areas, e.g. a shop close to the hospital site, were positive. Guo *et al.* [5] also measured surface and air concentrations of SARS-CoV-2 in an ICU and isolation ward in Wuhan. They similarly found widespread surface contamination and measurable aerosol concentrations of the virus in both areas, although higher air concentrations in the ICU (average 1400 copies m^{-3} near to patients).

In a study in biocontainment and quarantine areas of a hospital in the USA caring for 13 patients with Covid-19 [6], 77% of room surface samples and patient personal items were positive for SARS-CoV-2. Two-thirds of the room air samples were positive (mean concentration 2860 copies m^{-3}). All eight of the personal samples were positive (5400–67 000 copies m^{-3}). However, others have failed to detect airborne SARS-CoV-2 in hospitals [7,8].

These studies strongly indicate that the virus may be present in the air in hospitals and it is known that the aerosol may remain infective for a period of hours [9]. However, there is no reliable evidence on the concentration in different situations and none that relates to specific tasks. We do not know the inhaled dose required to cause infection, which may potentially be very low [10]. In such circumstances the most sensible strategy is to follow a precautionary approach and adopt good occupational hygiene principles.

The Principles of Good Control Practice, published by the British Health and Safety Executive (HSE) [11], sets out eight action areas, beginning with designing and operating activities to minimize emission, release and spread of hazardous agents. In general, there seems to be little attempt to do this in healthcare settings, although in principle there is no reason why this could not be done. The traditional approaches of partial enclosures, localized ventilation and other containment strategies could be applied. The healthcare sector needs to be more innovative in seeking out 'novel' interventions to prevent infection of those providing care.

Only later in the Good Control Practice list is PPE mentioned and only 'where adequate control of exposure cannot be achieved by other means'. However, this seems to be the main way that we attempt to protect workers; this is a topsy-turvy and likely ineffective approach to controlling a workplace hazard. PPE may be an effective control measure, but it should never be the prime control because it is dependent on the worker to use the equipment properly. HSE identify the reasons why PPE should not be relied upon:

- It has to be selected to fit each individual;
- It has to not interfere with their work or other PPE;
- It has to be correctly fitted each time it is worn;
- It has to remain properly fitted throughout the work;
- If reusable, it has to be properly stored, checked and maintained;
- It may be relatively easily damaged; and most importantly it fails to danger and may do so without warning.

In the short term we need to make the systems we have work as well as we can, but for the future we need to fix the system to protect workers from infectious risks.

There are basically three choices of respiratory protective equipment (RPE) that could be suitable for use in health and social care settings: surgical masks and disposable filtering facepiece (FFP) respirators with a face shield, and reusable powered air-purifying respirators (PAPRs). The first two approaches are commonly used at the moment and rely on the wearer fitting the device as closely as possible to the face. There are two relevant standards in Europe: FFP2 (nominally should reduce exposure by at least 75%) and FFP3 (with a nominal 95% reduction in inhaled concentration). The better fit to the face is an important reason why FFP respirators provide a better level of protection than surgical masks. Our research with fine dust suggests that wearing a surgical mask might on average reduce aerosol concentrations by ~70% but FFP respirators should on average reduce concentrations inhaled by >95% [12,13]. However, this relies on the mask fitting and being worn correctly. PAPRs on the other hand should provide a more consistent fit and a higher degree of protection, i.e. >99.9% reduction in aerosol concentration inhaled [14]. Brosseau [15] argues that a precautionary approach would suggest healthcare workers exposed to infectious aerosols should be provided with and trained to use respirators with high protection factors, such as PAPRs; we concur.

Until effective control at source is available, we propose a hierarchy of provisional inhalation exposure control measures, which would balance risk reduction with availability of supply:

- Public-facing workers, e.g. bus drivers or supermarket employees: either a barrier screen or visor and a surgical mask;
- Care workers where infected patients may be present: a visor and FFP3 respirator;
- Care workers in the vicinity of AGPs: minimum FFP3 and visor, but preferably a PAPR.

We have no doubt, if we were sending our loved ones into an ICU to undertake an AGP then we would want them to have the best protection possible.

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