Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

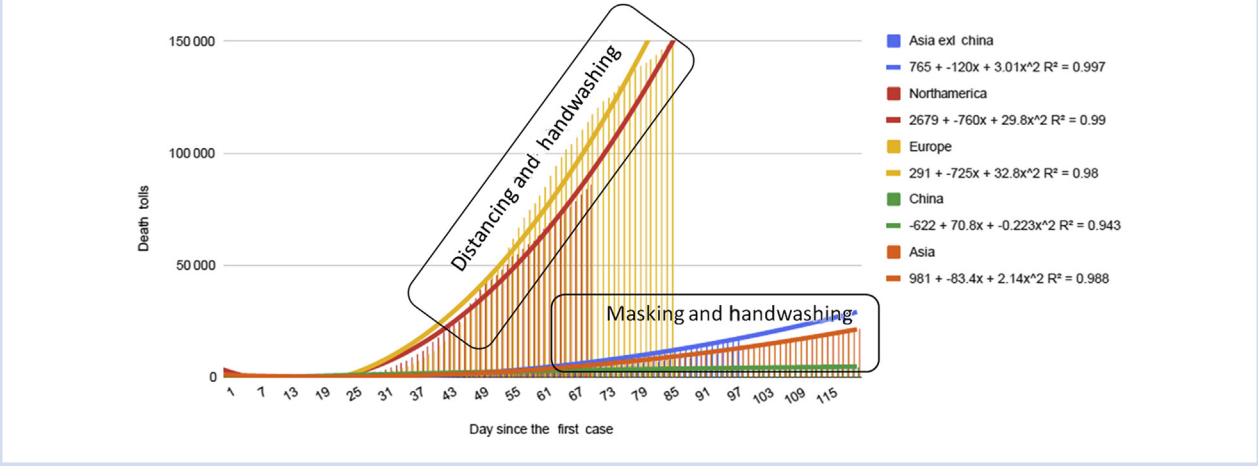

Fig. 1. Comparison of distinguished mortalities over time between the continentals advocating 'distancing and handwashing' *vs* 'masking and handwashing'.[3]

propose to continue safe mask wearing practices as a standard of care going forward.

Physical contact is the primary mechanism by which healthy people are exposed to severe acute respiratory syndrome coronavirus 2. Wearing masks is the most cost-effective way to slow viral spread and allow reopening of society. Experts in the field and lessons learned from other countries recommend that protective masks be worn by healthcare workers, patients, and their visitors, and this should become the new normal. The director of the CDC predicts that this will be one of the most important approaches to easing the burden of a possible resurgence of COVID-19 and flu in autumn. Not all hospitals require universal mask policies for all personnel in the hospital or medical staff. [6] With the shortages in proper PPE and the staunch culture of independence in the USA, it is understandable that implementing these protocols is difficult. However, without radical changes in attitudes and beliefs within the hospital setting and beyond, more frontline healthcare workers and others will be infected. We urge government officials and policymakers to evaluate and promote infection control measures, and prioritise frontline medical workers, their families, and their patients. We should take this opportunity to ease not only the challenges from the COVID-19 pandemic, but also other hospital-acquired infections, such as seasonal flu.

Declarations of interest

The authors declare that they have no conflicts of interest.

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COVID-19 and cardiopulmonary resuscitation: an N95 respirator mask may not be adequate

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Keywords: aerosol-generating procedure; cardiopulmonary resuscitation; COVID-19; healthcare worker; personal protective equipment; N95; powered air-purifying respirator

Editor—The coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is primarily spread by droplet (and perhaps aerosol) and contact transmission, with a fatality rate of about 3.1%.[1] At in-hospital 'code blue' activations for cardiac arrest, anaesthetists may be called to assist in airway management and cardiopulmonary resuscitation (CPR), in which various potentially aerosol-generating procedures are performed (e.g. face mask ventilation, intubation, and chest compression).[1,2] The European Resuscitation Council recommends that rescuers don personal protective equipment (PPE) before starting chest compressions even if this results in a brief delay.[1] The minimum recommended PPE is a filtering facepiece 3 (FFP3) respirator mask (FFP2 or N95 mask respirator if FFP3 is unavailable), eye and face protection, long-sleeved impermeable gown, and gloves.[1] Although delays are associated with increased morbidity and mortality, 'safety of staff is paramount'[1] as CPR associated bacterial and viral infection of healthcare workers has been reported.[3] The healthcare worker's duty of care to patients is associated with significant risks of infection and even death to themselves. The duty of care also extends to preventing onward transmission to other patients, their colleagues, their relatives, and the wider community.[1] the use of appropriate PPE is therefore key.

In a review of previous virus outbreaks and pandemics, most guidelines recommended the use of an N95 mask.[4] The N95 mask is a filtering, negative-pressure facepiece respirator, and its performance is highly dependent on a tight face seal.[2] However, there are three drawbacks with the N95 mask. First, it is inferior to an FFP3 mask, which is the first-line recommendation: the minimum filtration efficiencies of aerosol test particles are 95% and 99%, respectively.[2] Second, prior N95 mask fit testing does not ensure maintenance of a tight face seal.[2] Third, Recent studies show that N95 mask shape and vigorous movements may decrease its performance and ability to protect healthcare workers during CPR. In one simulation study, 61% of participants who fully passed N95 mask fit-testing (which included head nodding and bending)[3] failed at least one of three sessions of chest compression. Overall, 18% of participants experienced mask failures such as strap slipping.[3] In another simulation study, fold type N95 masks performed better than cup and valve-type N95 masks.[5] Adequate protection rates at baseline were 100%, 73.6%, and 87.5%, respectively; and during chest compressions they were 93.2%, 44.9%, and 59.5%, respectively.[5] This may have been related to the fixed shape of and increased leakage with the cup and valve-type N95 masks.[5]

During pandemic planning in which there is a risk of respirator supply depletion, there may be recommendations for N95 mask extended use ('wearing the same N95 respirator for repeated close contact encounters with several patients, without removing the respirator between patient encounters') and reuse ('by the same person with adequate reprocessing/decontamination').[6] However, the risk associated with extended use or reuse are: self-inoculation or transmission to others; contravening manufacturer's 'for single use only' instructions; decreased functionality; and additional discomfort.[6]

Better protection during CPR may be conferred with a powered air-purifying respirator (PAPR). PAPRs provide 2.5–100 times greater protection than N95 masks as indicated by their respective assigned protection factors.[2] The latter denotes the factor by which a respirator reduces aerosol contaminants in the ambient air, with a higher value indicating greater protection.[2] A recent meta-analysis concluded that use of a PAPR with a coverall may protect against the risk of contamination better than a N95 mask and gown [risk ratio (RR)=0.27].[7] Donning was, however, more difficult (non-compliance, RR=7.5) and was time-consuming in a recent simulation study,[8] which could have a negative impact on outcome.[7] PAPRs may also offer greater protection than officially assigned.[9] One study showed that a loose-fitting PAPR provided sufficient respiratory protection, with no disconnection of equipment or mechanical failures during chest compression.[10] However, over-breathing with inspiratory flow rates exceeding the PAPR flow rate can occur.[8] The resulting loss of positive pressure within the PAPR entrains air, but aerosol penetration remains low.[9] PAPRs are also more complex, require significant training, less readily available, and are associated with higher non-compliance and longer donning/doffing times that delay commencing CPR.[7,8,11] Both N95 masks and some PAPRs do not provide 'complete coverage of head and facial skin' as recommended for management of COVID-19 patients.[12] However, greater coverage is associated with increased difficulty during donning/doffing, discomfort, and contamination.[7] A comparison between PAPRs and the N95 mask is presented in Table 1.[5]

When PAPRs are not available, other PPE variations have been reported. These range from a full body suit (which provides a high level of droplet protection but low airborne reduction factors) with an N95 mask,[13] to elastomeric respirators.[2] Mechanical chest compression devices may also reduce infection risk by minimising the number of rescuers and circumventing the exposure risk from a shifting N95 mask during manual chest compressions.[1]

In conclusion, although the N95 mask is one of the minimum recommended respirators, recent evidence shows that it may not function well during CPR, and that PAPRs may be superior at decreasing contamination. Healthcare workers should be aware of the clinical, resource, and logistical limitations of both N95 masks and PAPRs.[8,11]

Table 1 Comparison of Powered Air-Purifying Respirator and N95 mask respirator.[2,5,7,10] HEPA, high-efficiency particulate air; PAPR, powered air-purifying respirator

	Powered Air-Purifying Respirator (PAPR)	N95 mask respirator
Protection (airborne)	Assigned protection factor 25–1000 99.97–100% test particles filtered HEPA filtered air Highest level of protection for aerosol-generating procedures	Assigned protection factor 10 95%/97%/99.97% test particles filtered depending on type of N95 mask
Area of coverage	Half and full face models, and hoods that cover head or neck and shoulders or all three	Nose, mouth, chin
Fit testing	Not required (except for some half-face models; e.g. CleanSpace™) Can be worn with facial hair	Required (costly, labour-intensive) Facial hair or features may preclude satisfactory fit
Training	Longer and regular training Pre-use check, donning/doffing sequence	Minimal training once fit-tested, disposable, and no set-up required
Risk of self-contamination	During donning/doffing	Increased risk if extended use or reuse
Availability and cost	Limited availability Initial cost high	High stock and easily accessible High cost if stockpiling/high use
Supply and maintenance	Reusable Battery recharging Require supply of filters Large storage space required	Disposable with 'extended use' and 'limited reuse' in certain circumstances Supply rapidly depleted when demand is high Hospitals urged to stockpile
Air flow and breathing	Positive inside to outside air flow Cooling effects Less respiratory effort needed No entrainment of outside air	Negative pressure devices Increases resistance to breathing Carbon dioxide rebreathing
Potential issues	Higher non-compliance of guidance During testing (e.g. failed flow test/disconnected circuit) During use (e.g. battery discharge and filter problems) Concerns about use in surgery because of outward airflow and risk of wound infection	Ineffective when moist, wet, or creased Face seal leak common
Impact on performance	Limited visual field Reduced hearing acuity (fan noise) Stethoscope use limited Claustrophobia Comfortable when worn for extended periods	User may experience headache, giddiness, breathless Silent, does not interfere with auscultation
Use during resuscitation	Battery failure, equipment disconnections, concerns that over-breathing exceeds flow rate	Risk of dislodgement and decreased performance

Declarations of interest

The authors declare that they have no conflicts of interest.

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Probability of fit failure with reuse of N95 mask respirators

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Keywords: COVID-19; extended use; fit test; N95 mask respirator; personal protective equipment; reuse

Editor—The 2019 coronavirus pandemic (COVID-19) has created a worldwide shortage of disposable N95 mask respirators that has led to extended use and reuse.[1–3] Multiple healthcare organisations[4] have implemented reuse of disposable N95 respirators designed for 8 h of use, for up to 20 days.[5] However, the durability and fit of respirators after multiple days of clinical reuse are unknown. A seal to the face is necessary to ensure that small aerosolised droplets are filtered. We conducted a cross-sectional pilot study to determine the effects of reuse and hydrogen peroxide vapour decontamination on the effectiveness of N95 respirators by qualitative fit testing.

This study was a voluntary, non-randomised, and low-risk quality improvement project; Institutional Review Board review and formal written consent were not required per institutional policy. From April to May 2020, a convenience sample of anaesthesiology clinical staff at an academic tertiary care centre who had within the past year passed fit testing of the same model of N95 mask respirator were included. Individuals who had worn their respirator for less than 1 day were excluded. All anaesthesiology clinical staff are trained yearly on performance of a self-performed user seal check and appropriate respirator use.

Before the start of the study, department management instructed clinicians to continuously record the number of days worn, times decontaminated with Food and Drug Administration approved Bioquell Z-2 vaporised hydrogen peroxide (Horsham, USA),[6] and times the N95 was donned. Before testing, participants self-reported the same information and if they believed the respirator provided a good fit. The participants were screened for COVID-19 risk by asking if they had any of the known symptoms and if their unprotected respirator was directly exposed to COVID-19 patients without subsequent decontamination. Exposed respirators that were not decontaminated were not tested. All six testing staff members were trained on appropriate fitting and testing directly by the Environmental Health and Safety Department. Qualitative fit testing was performed with denatonium benzoate (Bitrex®) in accordance with the Occupational Safety and Health Administration standard 1910.134 App A (3M, St. Paul, USA).[7] On a subset of participants (based on respirator availability) with fit failures, testing was repeated with a new N95 respirator of the same model. The data were analysed with logistic regression of binary fit failure using the R package cgam (R Foundation for Statistical Computing, Vienna, Austria) for flexible monotone increasing failure probabilities (Online Appendix).

Of 74 anaesthesia providers who participated in repeat fit testing, 46 were females and 28 were males. The females were more likely to fail fit testing (63% *vs* 29%; P=0.008). Ten participants wore the 1860 and 64 wore the 1804 VFlex™ (3M, St. Paul, USA). Figure 1 displays the estimated failure probability by number of days worn. The failure rate was 46% after 4 days (95% confidence interval [CI]: 31–63%), 50% after 10 days (95% CI: 36–63%), and 55% after 15 days (95% CI: 37–71%). Of respirators that passed fit testing, the median numbers of days worn were 7 (n=37; inter-quartile range [IQR]: 5–12) and 8 (n=37; IQR: 5–12) in the group that failed fit testing. The number of sterilizations had a modest association with