Australian Government

BE COVIDSAFE

Infection Control Expert Group

THE USE OF FACE MASKS AND RESPIRATORS IN THE CONTEXT OF COVID-19

28 October 2020 (revised 11 March 2021)

Contents

This guidance was developed by the Infection Control Expert Group (ICEG). It provides a summary of recent evidence around the use of face masks and respirators in the context of COVID-19. This guidance has general advice on the minimum requirements for the use of face masks and respirators. This advice is for for health and residential care workers and other occupational groups who may have contact with suspected or confirmed cases of COVID-19, or people in quarantine. Follow the jurisdictional guidance for your relevant state or territory.

Consider this advice alongside other advice from ICEG, including Minimising the risk of infectious respiratory disease transmission in the context of COVID-10: The hierarchy of controls.

There have been recent reports[1] of the emergence of more transmissible variants of SARS-CoV-2. This increase in transmissibility may relate to:

- higher viral load in people infected with one of these variants,
- increased duration of infectiousness, or
- increased propensity to bind to the ACE2 receptors on the cells of their susceptible contacts.

ICEG have reviewed and updated this advice on the use of masks and respirators in the care of COVID-19 patients. The updated advice reflects the increased level of uncertainty associated with emerging variants of concern (VOC) and ensures those at risk of infection are properly protected.

1. General considerations on the use of masks and respirators

Like most respiratory viruses, SARS-CoV-2 (the virus that causes COVID-19) is mainly spread by exposure of respiratory mucosae to virus-containing droplets. An infected person produces these when they speak, cough or sneeze.

SARS-CoV-2 is mainly transmitted by close personal contact (via respiratory droplets) or via contaminated fomites. It is less likely that transmission occurs via small respiratory particles (aerosols) that remain suspended in the air for prolonged periods. Airborne transmission is believed to mainly occur because of specific procedures or behaviours, in particular in poorly ventilated, crowded indoor settings. The procedures or behaviours include:

- aerosol-generating procedures (usually in healthcare settings);
- certain ('aerosol-generating') behaviours, such as singing, shouting and heavy breathing during strenuous exercise. This can produce increased amounts and forced expulsion of respiratory particles, including aerosols. These can travel and contaminate the environment, further than 1.5–2 m from the infected person.

Poor ventilation can increase the risk of airborne spread due to a low number of fresh air exchanges per hour. It can also direct air flow from an infection source towards, rather than away from, other people. Crowding exacerbates the risk.

The importance of different modes of transmission is still unknown. However, it is clear being close to an infected person carries the highest risk of infection. A mask (surgical or cloth) can be used by a person with a respiratory viral infection, including COVID-19, with or without

[1] WHO | SARS-CoV-2 Variants

symptoms. A mask can protect others by decreasing the spread of infected respiratory secretions. This is called source control. Please note, cloth masks are not suitable for use by health and residential care workers or quarantine workers.

Health and care workers (and some other occupational groups) use masks and particulate filter respirators (PFR) with eye protection[2] to provide respiratory protection. They use these when it is impractical or inappropriate to maintain physical distancing from a person with a respiratory infection, including COVID-19.

Masks and respirators are easily contaminated during use when adjusted by hands or during doffing. This creates an infection risk and underpins the importance of education in their proper use. Masks and respirators must have a good comfortable fit. Always perform effective hand hygiene before applying a mask or respirator and after doffing.

Some Australian states and territories also recommend or require the use of masks in indoor public places, in geographic areas with community transmission. This may include on public transport or at the shops.

In occupational settings, controls higher in the hierarchy of controls than personal protective equipment (PPE) such as masks and respirators, are more effective in managing risk. Always use more effective control measures in conjunction, rather than sole reliance on PPE.[3]

Employers or persons in control of workplaces have a responsibility to manage risks in the workplace. Risk management should be in accordance with work health and safety regulations,[4] and jurisdictional occupational health and safety legislation. Staff should be:

a) trained in infection prevention and control (IPC) practices relevant to infection risks and their individual roles, including use of PPE if appropriate, and

b) provided with working conditions and an environment that minimise risk and are conducive to compliance with appropriate IPC practices.

A mask or respirator is not a substitute for other precautions which must be used to prevent spread of COVID-19:

- **seeking testing** for COVID-19 if even mild respiratory symptoms develop or following close contact with someone with confirmed COVID-19,
- **staying at home when unwell,** with even mild respiratory symptoms or while awaiting the result of a test for COVID-19. **Especially if employed in a high-risk occupation such as health or aged care.** This is to protect others who are at increased risk of serious illness from COVID-19,
- **physical distancing** (staying >1.5 m away from others),
- **good internal ventilation** (including sufficient air exchanges and safe direction of flow),
- **hand hygiene** (avoid touching possibly contaminated surfaces), and
- **cough etiquette/respiratory hygiene.**

---

[2] Eye protection includes face shields, visors, wrap-around safety glasses and goggles. Prescription glasses are not adequate to protect the wearer from exposure to respiratory droplets.

[3] https://www.worksafe.vic.gov.au/hierarchy-control

[4] Safe Work Australia Model Work Health and Safety Regulations. December 2019.

Inappropriate use of masks and respirators can be associated with risk[5]:

- It is plausible, but unproven, that their use may give a false sense of security and lead to neglect of more important measures. These include, physical distancing, hand and respiratory hygiene.
- Touching the mask during use or when removing it can contaminate the hands or vice versa.
- Reuse of masks or respirators compounds the risks – Discard masks after use unless specified as reusable.; If reusable, masks and respirators should be reprocessed according to manufacturer's instructions.
- Masks and respirators are less effective if they become damp or damaged. They should be used in line with manufacturers' guidance. This also applies in clinical environments, where they should be used in accordance with established clinical protocols.

In places with little or no community transmission, wearing a mask is not essential and need not be mandated. Some states and territories in Australia may recommend or require the use of masks in public places or where physical distancing is not feasible, e.g. in public transport. This will depend on local COVID-19 epidemiology and public health advice.

See ICEG-endorsed infection control guidance on the Department of Health website for information on the use of PPE, including masks and respirators. This includes:

- Recommended minimum requirements for the use of masks or respirators by health and residential care workers in areas with significant community transmission
- Guidance on the use of personal protective equipment (PPE) in hospitals during the COVID-19 outbreak
- Guidelines for infection prevention and control in residential care facilities
- Guidance on use of personal protective equipment (PPE) in non-inpatient health care settings, during the COVID-19 outbreak

For detailed general information about Infection Prevention and control see the Australian Guidelines for the Prevention and Control of Infection in Healthcare.

1.1 Use of masks and respirators in health and residential care settings

In areas with **no, or a low level of, COVID-19 community transmission** use standard IPC precautions. This includes individual risk assessment to determine what control measures, including use of PPE such as a mask or respirator, are needed.

Risk assessment:

- is based on the patient's history and presentation,[6] the type of interaction, likelihood of exposure to body fluids and whether a procedure is (or is likely to be) required.

[5] RACP. COVID-19 Guidance on workplace risk management. https://www.racp.edu.au/docs/default-source/advocacy-library/covid-19-workplace-on-workplace-risk-management.pdf?sfvrsn=88f5f71a_4

[6] See case definitions in the COVID-19 National Guidelines for Public Health Units

- includes consideration of the rate of local community transmission or occurrence of local clusters of COVID-19.
- includes the worker's vulnerabilities (e.g. age and other risk factors).

To provide a higher level of protection for vulnerable patients or residents, some jurisdictions have adopted routine use of masks by health or residential care staff and visitors. This is to prevent introduction of viral infection by asymptomatic persons.

In areas with **community transmission of COVID-19**[7] and in specified clinical and other settings, routine use of transmission based precautions may be required. This is in addition to standard precautions, due to the high risk in these circumstances. In settings such as international airports and quarantine facilities, staff who cannot avoid close contact with people who may be infected with COVID-19, should use transmission-based precautions, in addition to standard precautions. The need for additional precautions is based on risk assessment.[8]

- In these circumstances, health and residential care workers need to ensure physical distancing from others when they remove their masks. This includes from other staff or members of the public (e.g. in cafeterias, meeting rooms, shared workspaces).

Health and care workers caring for patients with COVID-19 (or any infectious disease) and other workers needing respiratory protection should be trained in the correct use of relevant PPE. This includes choice, fitting, donning, and doffing of PPE such as masks and respirators. IPC professionals or other suitably trained educators should provide training, with safe working conditions.

1.2 Use of masks in non-health care settings

It is appropriate for occupational groups such as police, border, quarantine or other security staff or airport personnel to use masks and eye protection. These are needed when it is difficult to avoid close contact with suspected or confirmed COVID-19 cases, or those in quarantine. Observe physical distancing and hand hygiene at all other times.

Masks are also indicated for occupational groups in some high-risk non-health care workplaces. This includes where there is community transmission of COVID-19, when close contact cannot be avoided. Examples include corrective services or aircraft – where there is no known or suspected COVID-19 case, but a risk of introduction by a staff member or, in the case of aircraft, a passenger. The use of masks, by passengers and crew, is now strongly recommended on domestic and international aircraft in Australia and mandated in airport terminals in some states and territories.

Other occupational groups and service-providers who have face-to-face contact with the public should:

- practise physical distancing, and
- practise hand hygiene, and/or
- implement physical barriers, where possible.

[7] As defined by jurisdictional public health units.
[8] Recommended minimum requirements for the use of masks and respirators by health and residential care workers in areas with significant community transmission.

In geographical areas with COVID-19 community transmission, face masks may be recommended or required. This includes for the general public and for workers in settings where physical distancing is difficult to maintain, such as public transport or supermarkets.

There are ongoing risks of unexpected introduction of COVID-19 while the pandemic continues, globally. Therefore, certain basic precautions (hand hygiene, cough etiquette, being tested and staying home when unwell, physical distancing where feasible, and improving ventilation in indoor settings) may need to be maintained indefinitely in the community.

2. Evidence guiding recommendations for the use of masks or respirators in the context of COVID-19

2.1 Transmission of respiratory viruses

Bioaerosols contain suspended particles, produced from the respiratory tract during breathing, talking, coughing and sneezing (1). People with respiratory viral infections produce respiratory particles varying in size (from <0.1 to >100 microns in diameter). The amounts and proportions of viral RNA and viable virus they contain depend on the particle size and type and stage of infection (2-4). Particle sizes form a continuum, with no universally agreed cut-off between large and small, but there are important differences based on size.

Larger, wet particles (droplets generally defined as >5-10 microns, but often larger than 50 microns) travel relatively short distances from the source person (usually ~1-2 metres) before settling on surfaces, fomites or another person. Coughing, sneezing, shouting or singing and air currents may propel or carry respiratory particles to greater distances, but there is marked reduction in measured transmission potential at distances of >1 metre (5).

Large droplets can cause infection either:

- directly, by contacting the mucosae of the upper respiratory tract, or
- indirectly by settling on surfaces where they may be picked up by a person's hands before touching their eye, nose or mouth (6).

Respiratory droplet contamination of surfaces and fomites underlies the importance of hand and environmental hygiene in prevention of infection (7, 8).

Smaller and medium sized (< 50 micron) particles can remain suspended in the air for longer periods and be dispersed over long distances, depending on environmental conditions such as temperature, humidity, air currents and ventilation (9). They are capable of short or long-range transmission. Smaller particles can aggregate into larger droplets and settle onto nearby surfaces (10). Particles <5 micron are inspirable down to the alveolar space whilst particles <10 micron can reach below the glottis. The risk of transmission by smaller particles reduces as distance from the source increases and particles are diluted by dispersion (5, 6, 10). In quantitative terms, the larger particles contain by far the most virus.-(1, 6, 11).

Transmission of respiratory viral infections is most likely in humid, poorly ventilated indoor spaces, via large (droplets) and/or small particles (aerosols), among close contacts. Viral RNA can often be detected on surfaces and in particles circulating in the air in the vicinity of people with viral infections, such as influenza, SARS, MERS (12) and SARS-CoV-2 (13). Culturable virus is less often detected but this may be affected by the air sampling process *per se,* which is thought to reduce viral viability. Transmission is much less likely to occur outside, because of the limited range of large droplets and dilution by dispersion on air currents with rapid loss of viability of any virus carried by them, due to exposure to sunlight (14, 15).

Current evidence suggests that most respiratory viral infections are mainly spread directly or indirectly, between individuals in close proximity to each other. Modelling studies indicate the risk of infection from aerosols is many times less than from droplets or self-inoculation by contaminated hands (16). However, there is an increased risk of hospital-acquired respiratory viral infection, in the context of AGPs (17, 18). Controversy remains about the contribution of other factors to airborne transmission of respiratory viruses, including SARS-CoV-2. These include (18):

- the stage of the patient's infection and specific viral excretion dynamics
- the non uniform partitioning of excreted virus across different respiratory particle sizes
- whether the upper or lower respiratory tract is primarily involved
- to what extent the respiratory tract (upper or lower) is 'permissive' for a specific virus, i.e. presence of viral receptors[9] (18, 19)
- the presence of comorbidities[10] (20)
- the viral inoculum required to cause infection
- procedures or behaviours that may disperse infected aerosols and larger droplets across greater distances.
- environmental factors – airflow, temperature and humidity
- certain behaviours of an infected person, such as shouting, singing etc.

2.2 Transmission of SARS-CoV-2

Evidence to date suggests that, in common with other respiratory viruses, SARS-CoV-2 is mainly transmitted by close contact with an infected person. That is, directly by respiratory droplets or aerosols, or indirectly by contact with contaminated hands, surfaces or objects (20).

Surfaces contaminated by respiratory droplets can provide a persistent source of SARS-CoV-2. Viral RNA can often be detected on frequently touched surfaces and floors in the vicinity of patients with COVID-19 (21, 22); and live virus can persist, on some types of surface, for 2-3 days after experimental aerosolisation (23). These findings emphasise the potential for spread of SARS-CoV-2 by health care workers and the importance of hand and environmental hygiene.

Clinical and epidemiological evidence indicates COVID-19 is usually transmitted by close contact,

- in households,enclosed, household-like settings (24) such as residential care facilities (25, 26),
- cruise ships (27) and
- crowded workplaces (28), where physical distancing is impractical.

---

[9] The human upper respiratory tract appears to be non-permissive for MERS-CoV replication due to poor expression of its receptor, dipeptidyl peptidase 4 (DPP4) (18). In contrast, the SARS-COV-2 receptor (ACE2) is present in both upper and lower respiratory tracts and virus requires activation by a specific human cellular protease before cell entry.(20)

[10] ACE2 expression was elevated in the lungs of COVID-19 patients with comorbidities (hypertension, diabetes, and chronic obstructive lung disease) (20).

In the absence of effective preventive measures, the basic reproductive number (R_0)[11] of COVID-19 is 2-3 (29). Household attack rates are highly variable; in a systematic review of 13 studies, they varied from ~5~50%, but most were around 10%-20% (30). This contrasts with much higher R_0s and household attack rates of infections in which airborne transmission across distance occurs regularly, including:

- measles (R_0,12-18; household attack rate 90%),
- varicella, (R_0 ~10, household attack rate 85%) (18) and
- tuberculosis (31).

These data add support to the contention that airborne transmission of SARS-CoV-2 across larger distances is relatively uncommon (32-34), although some dispute this (35). However, accumulating reports of:

a) detection of viral RNA (and/or live virus) at a distance from the infected person
b) transmission of SARS-CoV-2 in the absence of obvious breaches of IPC, and
c) reports of variant strains with increased transmissibility, contribute to controversy and emphasise that our understanding of SARS-CoV-2 transmission and the optimal measures to prevent transmission are still incomplete.

There is little clinical or epidemiological evidence that airborne transmission of SARS-CoV-2, at distances greater than 1.5 m occurs frequently in well ventilated settings. However, by analogy with influenza, SARS and MERS (36, 37), there is likely to be a small contribution from aerosols (33, 38), with uncertain significance for IPC (4, 39). There are significant differences between COVID-19 and these other infections. The SARS-CoV-2 viral load in the upper respiratory tract is high in early infection, even when symptoms are mild (40), and it declines in the second week, when symptom severity often increases (21, 41-43). By contrast, in SARS the viral load correlated with disease severity and peaked in the second week of illness (44, 45).

Recently-described new variants of SARS-CoV-2 are associated with:

- higher rates of transmission (46), thought to be due to an increased viral load early on in the infection,
- presumed increase in the amount and duration of viral shedding, and
- a mutation that may mediate increased affinity of the spike protein with the ACE2 host cell receptor (47).

In common with SARS and MERS, COVID-19 has been associated with superspreading events in which case clusters have resulted from exposure to one or more highly infectious individuals present at a gathering in an enclosed space. Examples include public transport, choir practice, weddings, religious venue, bars, restaurant or nursing homes (48).

Comparable situations have been reported in Australian hospitals. Increased risks of healthcare worker (HCW) infections were associated with multi-bed rooms, with suboptimal ventilation, in

[11] The basic reproduction number (R0 or reproductive rate, is an epidemiologic metric used to describe the contagiousness or transmissibility of infectious agents.

which there were delirious or distressed patients who were wandering and crying out or shouting. These contributed to a critical burden of infection and heavy workload (49). It is plausible these circumstances result in increased density of respiratory droplets and aerosols, with greater force and range of expulsion and delayed dispersal. This has, understandably, prompted the use of PFRs, such as P2 or N95, in these settings. It is not clear whether this would significantly reduce the risk of HCW infections, without additional protective measures from the hierarchy of controls.[12]

SARS-CoV-2 RNA has been detected by PCR in air samples and on surfaces in the vicinity of COVID-19 patients, especially in the first week of illness (21). In one study detection of viral RNA, at low levels, was more likely in air samples from intensive care units, up to 4 metres from patients, than in general wards; it was widely distributed on floor, bed rail, locker handle, cardiac table etc. (22). Few studies have attempted viral culture, but some have demonstrated viable virus in air samples (50).

2.3. Implications for respiratory protection against COVID-19

Effective respiratory protection programs require implementation of a broad range of administrative and engineering controls in addition to PPE. Source control (generally use of a surgical mask) is required where appropriate (e.g for confirmed or suspected cases of COVID-19 and individuals with relevant symptoms). Protect eyes with protective eyewear or a face shield. Wear either a mask or PFR to protect the nose and mouth from infected respiratory droplets.

Surgical masks for use in healthcare in Australia must conform with the Australian Standard AS4381:2015, which specifies masks must provide a measurable barrier to a *Staphylococcus aureus* bacterial aerosol (1 micron) particles.[13] Fluid resistant surgical masks also prevent penetration by splashes. A range of evaluations have shown that surgical masks are effective for source control i.e. reducing particle emission from the wearer (51, 52).

In a hamster model, the use of a partition of surgical mask material significantly reduced transmission of SARS-CoV-2 from infected to exposed naïve, hamsters via respiratory droplets and/or aerosols (53). In contrast to PFRs, surgical masks do not generally provide a close fit to the face. Quantitative fit testing has shown that surgical masks achieve inadequate fit factors ranging from 2.5-9.6 (expected value for PFRs is >100) (54). However, a recent simulation study, that compared surgical masks to PFRs for source and transmission control, found that *neither* surgical masks *nor* N95 PFR completely blocked transmission of virus droplets/aerosols even when completely sealed (51).

Systematic reviews of randomised controlled trials (RCTs) that have directly compared the efficacies of surgical masks and PFRs and shown equivalent protection against respiratory viral infections, with transmission modes similar to those of COVID-19 (55-57). A meta-analysis of six RCTs involving more than 9000 participants showed no statistically significant differences in relative risks of laboratory-confirmed influenza and other viral infections or influenza-like illnesses, between groups using N95 respirators or surgical masks (57). Further analysis of three

[12] See Minimising the risk of infectious respiratory disease transmission in the context of COVID-19: The Hierarchy of controls

[13] https://www.atfa.com.au/wp-content/uploads/2020/04/Australian-Standard-for-Single-use-face-masks.pdf

studies in health care settings, showed the risks of laboratory-confirmed viral infections were similar in both groups, but significantly less than in a control group that did not use masks (58).

In summary, whilst surgical masks provide a level of respiratory protection against SARS-CoV-2 acquisition, this *may* be inferior to that provided by properly fitted PFRs although no direct comparison has been reported. However, the findings of *in vitro* and simulation studies of *efficacy*, are often contrary to studies of *effectiveness* (and day-to-day experience), which suggests that other factors associated with use are important, such as comfort and tolerability for the wearer. A current randomised trial is underway that is a direct comparison of surgical masks versus PFRs for COVID19 patient care. It is due to finish recruitment in April 2021[14].

Obviously, the use of surgical masks or PFRs alone will not eliminate the risk of HCW COVID-19 infections; it also reflects community prevalence, environmental factors and implementation of a full range of IPC and risk management measures, in all areas of the workplace (including staff meeting and tea rooms, segregation zones and other areas where people interact).

The WHO Infection Prevention and Control Research and Development Expert Group for COVID-19 (59) and several others (50, 60, 61) have concluded there is no robust clinical or epidemiological evidence to support the routine use of airborne precautions for COVID19 patient care except in the specific context of high-risk AGPs (37).

Considering the uncertainty around the emergence of new highly transmissible variants of SARS-CoV-2 and the implications for respiratory protection, the use of fit-tested PFRs (i.e. airborne precautions) for all clinical care (or other unavoidable close contact) involving close patient contact is now, increasingly, being considered or implemented. However, others note that COVID-19 infections in health care workers have usually occurred in situations where ventilation, working conditions (excessive staff workload, fatigue and overcrowding) and use of PPE generally (including not wearing eye protection) have been suboptimal.

Routine use of PFRs in the settings described above is unlikely to provide significant benefit without concurrent implementation of higher level controls (engineering and administrative). A broad programme of fit testing and assiduous training programs for relevant staff are also required. This will ensure that management of all aspects of airborne precautions is safe and consistent with adverse effects minimised. In lower risk settings surgical masks remain adequate provided they are of appropriate quality, properly fitted and used correctly in conjunction with eye protection.

2.4. Aerosol-generating procedures (AGPs)

A systematic review (37) of 10 retrospective studies from the SARS era indicates some AGPs were associated with an increased risk of SARS among health care workers. Limited types of procedure and relatively small numbers of health care workers exposed to each, were assessed in the studies reviewed. The authors acknowledged that, although most studies showed that risks were mitigated by the use of PPE, they could not assess compliance. None of the studies directly compared risks based on use of either surgical masks or PFRs.

Tracheal intubation was most consistently associated with increased risk across multiple studies. Other procedures associated with a significantly increased risk, based on a small

[14] https://clinicaltrials.gov/ct2/show/NCT04296643

number of studies, included non-invasive ventilation, manual ventilation before intubation and tracheostomy.

Pooled estimates suggested that increased risks associated with suction before or after intubation, bronchoscopy, nasogastric tube insertion, cardiac compression and defibrillation could not be excluded, but odds ratios were not significantly different.

Special consideration for cardiopulmonary resuscitation (CPR)

Because of its status as a lifesaving, emergency procedure, special consideration is warranted for CPR. The systematic review (37) suggested that, while CPR was associated with an increased risk of SARS transmission, cardiac compression, alone, was not, in two of the studies reviewed (62, 63). The authors of a third study, in which there was an apparently increased risk, stated that ”Chest *compression and intubation were …highly correlated and ….distinction between those two is not possible*” (64), indicating a significant confounding effect of intubation.

These studies suggest that, in the context of a low rate of community transmission of COVID-19, cardiac compression and defibrillation are unlikely to pose a significant risk to first responders or bystanders who commence cardiac compression, without knowledge of the subject’s COVID-19 status. In a hospital setting, any risk can be mitigated by the use of a surgical mask or by covering the patient’s mouth with a fabric which will not obstruct breathing. A clinician who subsequently performs airway manoeuvres should use airborne precautions (i.e. use of a PFR).

Based on limited evidence, the systematic review (37) found no increased risk of transmission for: bi-level positive airway pressure ventilation (BiPAP), endotracheal aspiration, suction of body fluids, mechanical ventilation, manual ventilation, manual ventilation after intubation, high-frequency oscillatory ventilation, administration of oxygen, high-flow nasal oxygen, chest physiotherapy or collection of sputum samples.

However, the absence of evidence does not prove absence of risk. Therefore, based on similarities with high-risk procedures, most authorities (65-68) recommend standard, contact, droplet **and** airborne precautions (i.e. a PFR instead of, not in addition to, a surgical mask), be used in the management of COVID-19 patients likely to require frequent AGPs or who exhibit certain behaviours. These include behaviours likely to produce respiratory secretions, with greater force and range (e.g. loud crying, shouting) in a poorly ventilated space.

The following examples of AGPs, potentially associated with increased COVID-19 transmission risk, are based on limited evidence but consistent with advice from other authorities (37, 58, 66).

Examples of AGPs that may be associated with risk of COVID-19 transmission

Instrumentation or surgical procedures on the respiratory tract

- Insertion or removal of an endotracheal tube and related procedures e.g. manual ventilation and open suctioning of the respiratory tract
- Bronchoscopy and upper airway procedures that involve open suctioning
- Tracheotomy/tracheostomy (insertion, removal, open suctioning)
- Ear-nose-throat, faciomaxilliary or transphenoidal surgery; thoracic surgery involving the lung.
- Post-mortem procedures involving use of high speed devices on respiratory tract tissues

- Disconnection/reconnection of a closed ventilator circuit, intentionally or accidentally.

Other procedures that may generate respiratory aerosols

- Manual or non-invasive ventilation (NIV): BiPAP; continuous positive airway pressure ventilation (CPAP)
- Collection of induced sputum
- High flow nasal oxygen
- Upper gastrointestinal instrumentation that involves open suctioning of upper respiratory tract
- Some dental procedures e.g. involving high speed drilling.

Avoid use of nebulisers. Use alternative devices for administration of medication (e.g. spacers).

3. Recommendations for use of surgical masks and particulate filter respirators by health and care workers in the context of COVID-19[15]

3.1. Surgical masks

Surgical masks are disposable masks with an Australian Register of Therapeutic Goods (ARTG) number. Surgical masks protect the nose and mouth from large and small droplets. Most surgical masks are fluid (splash) repellent to differing degrees. There are three defined levels (see Appendix 1). Level 2 or 3 masks, with a higher degree of splash resistance, are preferred during procedures in which there is a risk of body fluid splash. Level 1 masks are acceptable for general patient care, procedures where the risk of body fluid exposure is judged to be small, or for use by individuals for source control. Note that eye protection is also required for full protection against droplet transmission of respiratory infections.

Indications for use of surgical masks by health and care workers in the context of COVID-19

In hospital and community health care settings, use surgical masks and protective eyewear (at a minimum) during routine care of patients with suspected or confirmed COVID-19, and those in quarantine.

ICEG do not recommend routine (universal) use of surgical masks in the care of patients with no clinical or epidemiological indication of COVID-19, *except* in communities or health care settings in which there is a higher-risk of COVID-19 transmission (as defined by jurisdictional public health units).

Note transmission-based precautions (contact and droplet) require use of a surgical mask and eye protection for close clinical contact with patients with acute respiratory symptoms, regardless of known viral infection status or community prevalence of COVID-19.

Indications for the use of surgical masks by patients to prevent transmission of COVID-19

[15] For technical details of different types of masks and respirators see Appendix 1.

Patients with suspected or confirmed COVID-19, or those in quarantine because of close contact with a confirmed case, international travel or other exposure, within the previous 14 days, should be given a surgical mask to wear when they are likely to come into contact with others. This includes when being transferred within or between health care facilities. Provide patients with instructions about correct use.

Precautions when using surgical masks by health and care workers in the care of patients with COVID-19

It is important to avoid touching the front of a mask. Always cover the nose and wear masks appropriately i.e. not around the neck or pushed up on forehead. Replace the mask if it becomes contaminated, damaged or damp and remove it carefully by touching only the straps, to avoid self-contamination. Perform hand hygiene before donning and after doffing a mask. Do not store or reuse surgical masks after doffing.

3.2. Particulate filter respirators

Particulate filter respirators (PFRs), such as P2, N95 or equivalent, are used to protect the wearer from exposure to small airborne particles. Different types of PFR are often used interchangeably, but while similar, they are not identical. PFRs should meet the requirements of AS/NZS1716:2012 or other relevant standard (See Appendix 1 for more detail).

PFRs should only be used when indicated by a risk assessment. To be effective, a tight facial seal is necessary. In health care settings, their use is recommended for high-risk AGPs (see 2.4 above) and protection against infections known to be spread by the airborne route such as tuberculosis or measles. Their use should also be considered in some clinical situations when caring for patients with COVID-19 patients whose clinical status is unstable and or behaviour unpredictable.[16]

Training in the use - including fit checking - of PFRs, each time they are used, is needed for safe and effective use. Ideally, donning and doffing of PPE should be supervised when airborne precautions are indicated to ensure the correct PFR for that person is used and it is applied correctly and removed safely. Comfort is important; staff with painful pressure areas or skin reactions (69) from prolonged or repeated PFR use cannot be expected to wear a PFR safely.

Indications for use of PFRs

When caring for patients with suspected or confirmed COVID-19 (including in the context of a SARS-CoV-2 variant of concern) or who are in quarantine, PFRs are recommended for:

- proceduralists and their assistants performing high-risk AGPs including instrumentation and/or surgical procedures involving the upper or lower respiratory tract of patients (65);
- clinicians caring for patients for whom an AGP is required in any clinical setting;
- clinicians in critical care or other high-risk settings, caring for patients in whom AGPs are, or are likely to be, required frequently.

[16] https://www.health.gov.au/resources/publications/guidance-on-the-use-of-personal-protective-equipment-ppe-in-hospitals-during-the-covid-19-outbreak

In some other specified clinical settings, in areas with COVID-19 community transmission (defined by jurisdictional public health units), HCWs may need to use a PFR instead of (not in addition to) a surgical mask. Use a PFR (airborne precautions) in addition to other standard contact and droplet precautions.[17] If there is a risk of body fluid splashing in such a setting, the PFR should be certified fluid resistant (i.e. surgical grade) or covered by another barrier such as a face shield.

Precautions when using PFRs

Standard, contact and airborne precautions must be closely observed, when using a PFR, to ensure optimal protection against COVID-19 during an AGP.

It is important to avoid touching the front of a PFR during use and removal, to avoid self-contamination. Perform hand hygiene immediately after removal of a PFR.

Disgard single use PFRs as soon as they are removed. They should not be stored or decontaminated for reuse except by a properly validated method (see Appendix 1).[18]

Extended use of PFRs

You can use a PFR continuously for a single session of care. If removed e.g. for a meal break or drink, it should be discarded and replaced with a new one. A correctly fitted PFR (i.e. with adequate face-seal), often becomes uncomfortable with prolonged use. Prolonged use can cause headache, thermal stress, painful pressure on the bridge of the nose and/or adverse respiratory and dermatological effects (54-56,69). If any of these occur the wearer is more likely to unconsciously loosen or adjust it and risk contaminating their hands and face or be noncompliant with its use.

How to fit and use PFRs safely

There are two complementary methods of fitting a PFR to the size and shape of an individual's face: **fit-testing** - a specialised procedure - and **fit-checking** - a series of steps the wearer performs each time they use a PFR.

Fit testing: A facial fit test is a method of matching a respirator to an individual as defined under the Australian/New Zealand Standard 1715 2009.[19] Its aim is to identify a specific type, model and size of PFR that can provide an adequate facial seal for different individuals' faces (which vary in size and shape). A facial seal ensures that the respirator fits the user's face snugly without gaps between the skin and the respirator that could allow respiratory particles to bypass the filter.

As described in AS/NZ 1715 2009, fit-testing methods are either: qualitative (based on whether an odour or taste-test reagent is excluded from the wearer's perception); or quantitative (in which the ratio of ambient generated salt particles detected on either side of the mask. The 'fit factor' – is measured during different activities).[16] During testing, individuals who are trained in performing fit-testing can also provide useful instruction in the correct use of PFRs (70).

---

[17] *Recommended minimum requirements for the use of masks and respirators by health and residential care workers in areas with significant community transmission*
[18] https://www.tga.gov.au/behind-news/reuse-face-masks-and-gowns-during-covid-19-pandemic
[19] https://www.standards.org.au/standards-catalogue/sa-snz/publicsafety/sf-010/as-slash-nzs--1715-2009

Facial hair that underlies the edge of a PFR prevents an adequate seal. If present, the hair should be shaved or an alternative type of respirator used (e.g. PAPR, see below). Do not perform high-risk AGPs unless a satisfactory fit-check has been achieved.

Until recently, fit testing has not been widely practised in Australian health care. Fit testing programs especially in the context of COVID-19 rely on resources, adequate supplies, range of types and sizes of PFRs and fit testing expertise that matches the expected standards of health care. Fit-testing should be prioritised to health and care workers who frequently perform or assist with AGPs or work in situations where risk assessment has identified that a PFR is required. Work health and safety regulations stipulate[20] that it is the workplace responsibility to ensure that properly fitted PPE is available to staff as required.

Note: Fit-testing does not guarantee that a PFR will not leak during future use – it does not replace the need for fit-checking each time a PFR is used (70, 71). Even after successful fit testing, the facial seal of a PFR may not be maintained over time, because of changes in facial shape. Repeat fit-testing when new types of PFRs are introduced.

Fit-checking: Fit-checking is the most reliable way to ensure an adequate facial seal on each occasion. Perform fit-checking each time a PFR is used, regardless of whether previous fit-testing was performed. Its purpose is to ensure that the specific PFR to be used fits the user's face snugly (i.e. creates a seal) on each occasion of use to ensure that respiratory particles do not bypass the filter. The respirator must be put on, fitted and removed correctly.

Users should be trained in the correct method of fitting, removing and fit checking PFRs. Appropriate training can improve respirator facial seal achieved by fit-checking (70, 71).

Note: Even a properly fitted PFR cannot guarantee protection against COVID-19, because of the diverse modes of transmission of SARS-CoV-2. Consider the increased complexity of fitting and training, and the potential discomfort or adverse effects of prolonged use, when considering the relative merits of PFRs vs surgical masks for protection of HCWs, during routine care of COVID-19 patients.

Reprocessing of PFRs

PFRs are generally single use. In times of severe shortage, reprocessing is sometimes considered. This should only be contemplated if a properly validated process is available. The following warning from the Australian Therapeutic Goods Administration should be heeded:

"*If you are reprocessing medical devices for reuse, you will need to meet the legislative definition of a manufacturer. You will therefore need to meet all the responsibilities of a manufacturer under the therapeutic goods legislation and regulations. You are assuming the responsibility and liability should the device fail to perform as intended*".[21]

[20] Safe Work Australia's How to manage work health and safety risks. Code of practice

[21] https://www.tga.gov.au/behind-news/reuse-face-masks-and-gowns-during-covid-19-pandemic

3.3 Powered air-purifying respirators (PAPRs)

The use of a PAPR, may be considered in certain situations when airborne precautions are required, based on a risk assessment, anticipated duration of exposure to aerosols, the training of the HCW and the type(s) of PAPR available.

If a HCW needs to remain in a COVID-19 patient's room continuously for prolonged periods e.g. >1 hour, during which multiple procedures are likely to be performed, the use of a PAPR may be considered for additional comfort and visibility. This is if a tight facial seal cannot be achieved or if adverse effects have been experienced with extended use of PFRs.

Several different types of relatively lightweight, comfortable PAPRs are available. They should be used according to the manufacturer's instructions, including reprocessing of reusable PAPR components and maintenance of filters

PAPRs must only be used by HCWs who have been trained in the use of the specific type of PAPR chosen. Take care during removal of a PAPR, which is associated with a risk of contamination. Perfrom hand hygiene after removing the PAPR.

PAPRs designed for use in settings outside of health care are *not recommended.*

Only PPE included in the ARTG should be used in hospitals or for surgical procedures.

Only PPE marked as reusable should be reused. They must be decontaminated and reprocessed according to the manufacturer's instructions. All other PPE must be discarded after use.

APPENDIX 1: Disposable Mask Types and Protective Eyewear

Surgical masks

Surgical masks are disposable covers that go over the mouth and nose. They are used by health and residential care workers as a component of standard and droplet precautions, to prevent sprays or splashes of body fluid coming into contact with the wearer's mouth and nose and protect the mucosae from contamination. Surgical masks can also be worn by people for source control. Information about the regulation of surgical masks is available on the TGA website.

Surgical masks are not designed to protect the wearer from infectious agents transmitted via the airborne route. However, aerosol protection is documented, albeit at a lower level (61,57); and the standard specifies that the mask must withstand a 1 micron bacterial penetration test. Surgical masks are also valuable for source control.

Table 1 (below) shows the 3 levels of surgical masks and their application in medical practice.

Table 1: Levels of surgical masks and their application[22]

Level 1 barrier	Level 2 barrier	Level 3 barrier
For general medical procedures, where the wearer is not at risk of blood or body fluid splash, or to protect staff and/or the patient from droplet exposure	For use in procedures where minimal blood or droplet exposure is likely e.g. changing dressings on small or healing wounds	For all surgical procedures, major trauma, first aid or in any setting in which the HCW is at risk of bloody or body fluid splash

The wearing of correctly fitted surgical masks by patients known or suspected to be infected with agents transmitted by respiratory droplets, reduces transmission by preventing dispersal of respiratory secretions into the air.

Particulate filter respirators

PFRs, also known as filtering facepiece respirators or disposable respirators, are a component of airborne precautions and are comprised of multiple layers which filter particles through mechanical impaction and electrostatic capture (65). PFRs are intended to provide a good facial fit to minimise aerosol contamination of the mucous membranes of the nose and mouth (65).

PFRs are certified as having met specific regulatory standards. Such standards specify the required physical properties and performance characteristics which must be met in order for respirators to claim compliance with the relevant standard (66).

Around the world, the following performance standards apply:

---

[22] Adapted from Australian Commission on Safety and Quality in Health Care. Australian Guidelines for the Prevention and Control of Infection in Healthcare. NHMRC. 2019. https://www.nhmrc.gov.au/about-us/publications/australian-guidelines-prevention-and-control-infection-healthcare-2019

- P2 (Australia/New Zealand AS/NZA 1716:2012)
- N95 (United States NIOSH-42CFR84)
- FFP2 (Europe EN 149-2001)
- KN95 (China GB2626-2006)
- Korea 1st class (Korea KMOEL - 2017-64)
- DS2 (Japan JMHLW-Notification 214, 2018)

PFRs certified as compliant with these standards have very similar function to one another. There may be some variation in the flow rate specified by different standards; inhalation and exhalation resistance testing flow rates range between 40 and 160 L/min, and 30 and 95 L/min, respectively. However, the standards' various pressure drop requirements are quite similar.

Table 2 (below) shows a summary comparison of the different performance characteristics of PFR certifications under the relevant standard. Based on this comparison, KN95, P2, Korea 1st Class, and Japan DS2 respirators are generally regarded as equivalent to US N95 and European FFP2 respirators (60). Purchasers are advised to check the Therapeutic Good Administration website for further information about individual PFRs.

Table 2: Comparison of PFRs[23]

Certification/ Class (Standard)	N95 (NIOSH-42C FR84)	FFP2 (EN 149-2001)	KN95 (GB2626-2006)	P2 (AS/NZ 1716:2012)	Korea 1st Class (KMOEL - 2017-64)	DS2 (Japan JMHLW Notification214, 2018)
Filter performance (must be ≥ x% efficient)	≥ 95%	≥ 94%	≥ 95%	≥ 94%	≥ 94%	≥ 95%
Test agent	NaCl	NaCl and paraffin oil	NaCl	NaCl	NaCl and paraffin oil	NaCl
Flow rate	85 L/min	95 L/min	85 L/min	95 L/min	95 L/min	85 L/min
Inhalation resistance – max pressure drop	≤ 343 Pa	≤ 70 Pa (at 30 L/min) ≤ 240 Pa (at 95 L/min) ≤ 500 Pa (clogging)	≤ 350 Pa	≤ 70 Pa (at 30 L/min) ≤ 240 Pa (at 95 L/min)	≤ 70 Pa (at 30 L/min) ≤ 240 Pa (at 95 L/min)	≤ 70 Pa (w/valve) ≤ 50 Pa (no valve)
Flow rate	85 L/min	Varied	85 L/min	Varied	Varied	40 L/min
Exhalation résistance – max pressure drop	≤ 345 Pa	≤ 300 Pa	≤ 250 Pa	≤ 120 Pa	≤ 300 Pa	≤ 70 Pa (with valve) ≤ 50 Pa (no valve)
Flow rate	85 L/min	160 L/min	85 L/min	85 L/min	160 L/min	40 L/min
Exhalation valve leakage requirement	Leak rate ≤ 30 mL/min	N/A	Depressur-isation to 0 Pa ≤ 20 sec	Leak rate ≤ 30 mL/min	Visual inspection after 300 L/min for 30 sec	Depressurisation to 0 Pa ≤ 15 sec
Force applied	-245 Pa	N/A	-1180 Pa	-250 Pa	N/A	-1470 Pa
CO2 clearance requirement	N/A	≤ 1%	≤ 1%	≤ 1%	≤ 1%	≤ 1%

[23] Adapted from 3M Technical Bulletin. Comparison of FFP2, KN95, and N95 and Other Filtering Facepiece Respirator Classes, Revision 3. 2020 19 May 2020. https://multimedia.3m.com/mws/media/1791500O/comparison-ffp2-kn95-n95-filtering-facepiece-respirator-classes-tb.pdf

Protective eyewear[24]

Protective eyewear protects health care and other frontline workers against ocular transmission by protecting the mucous membranes of the eyes from potential contamination. Protective eyewear can also prevent people from touching their eyes and face.

Examples of protective eyewear include face shields, goggles and safety glasses. Goggles or safely glasses must be closely fitted, wrap-around style and meet Australian standards (AS/NZS 1337.1:2010). Prescription glasses or safety glasses that are not wrap-around offer inadequate protection and should not be used. Face shields can be single-use or reusable (as detailed in the manufacturers instructions for use). Face shields offer additional protection against splashes and sprays of blood and other body fluids in front of the mask. Face shields should extend to the ears on the sides and below the chin. Face shields do not replace the need for a mask or respirator.

[24] DHHS Victoria, Use of eye protection for healthcare https://www.dhhs.vic.gov.au/factsheet-eye-ppe-guidance-healthcare-workers-covid-19-doc

References

1. Gralton J, Tovey E, McLaws ML, Rawlinson WD. The role of particle size in aerosolised pathogen transmission: a review. J Infect. 2011;62(1):1-13. https://www.ncbi.nlm.nih.gov/pubmed/21094184

2. Gralton J, Tovey ER, McLaws ML, Rawlinson WD. Respiratory virus RNA is detectable in airborne and droplet particles. J Med Virol. 2013;85(12):2151-9. https://www.ncbi.nlm.nih.gov/pubmed/23959825

3. Leung NHL, Chu DKW, Shiu EYC, Chan KH, McDevitt JJ, Hau BJP, et al. Respiratory virus shedding in exhaled breath and efficacy of face masks. Nat Med. 2020;26:676-80. https://www.ncbi.nlm.nih.gov/pubmed/32371934

4. Fennelly KP. Particle sizes of infectious aerosols: implications for infection control. Lancet Respir Med. 2020;8(9):914-24. https://www.ncbi.nlm.nih.gov/pubmed/32717211

5. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schunemann HJ, et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. Lancet. 2020;395(10242):1973-87. https://www.ncbi.nlm.nih.gov/pubmed/32497510

6. Thomas RJ. Particle size and pathogenicity in the respiratory tract. Virulence. 2013;4(8):847-58. https://www.ncbi.nlm.nih.gov/pubmed/24225380

7. Boone SA, Gerba CP. Significance of fomites in the spread of respiratory and enteric viral disease. Appl Environ Microbiol. 2007;73(6):1687-96. https://www.ncbi.nlm.nih.gov/pubmed/17220247

8. Ikonen N, Savolainen-Kopra C, Enstone JE, Kulmala I, Pasanen P, Salmela A, et al. Deposition of respiratory virus pathogens on frequently touched surfaces at airports. BMC Infect Dis. 2018;18(1):437. https://www.ncbi.nlm.nih.gov/pubmed/30157776

9. Li S, Eisenberg JN, Spicknall IH, Koopman JS. Dynamics and control of infections transmitted from person to person through the environment. Am J Epidemiol. 2009;170(2):257-65. https://www.ncbi.nlm.nih.gov/pubmed/19474071

10. Stilianakis NI, Drossinos Y. Dynamics of infectious disease transmission by inhalable respiratory droplets. J R Soc Interface. 2010;7(50):1355-66. https://www.ncbi.nlm.nih.gov/pubmed/20164087

11. Brown JR, Tang JW, Pankhurst L, Klein N, Gant V, Lai KM, et al. Influenza virus survival in aerosols and estimates of viable virus loss resulting from aerosolization and air-sampling. J Hosp Infect. 2015;91(3):278-81. https://www.ncbi.nlm.nih.gov/pubmed/26412395

12. Shiu EYC, Leung NHL, Cowling BJ. Controversy around airborne versus droplet transmission of respiratory viruses: implication for infection prevention. Curr Opin Infect Dis. 2019;32(4):372-9. https://www.ncbi.nlm.nih.gov/pubmed/31259864

13. Liu Y, Ning Z, Chen Y, Guo M, Liu Y, Gali NK, et al. Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. Nature. 2020;582:557-61. https://www.ncbi.nlm.nih.gov/pubmed/32340022

14. Schuit M, Ratnesar-Shumate S, Yolitz J, Williams G, Weaver W, Green B, et al. Airborne SARS-CoV-2 Is rapidly inactivated by simulated sunlight. J Infect Dis. 2020;222(4):564-71. https://www.ncbi.nlm.nih.gov/pubmed/32525979

15. Ratnesar-Shumate S, Williams G, Green B, Krause M, Holland B, Wood S, et al. Simulated Sunlight rapidly inactivates SARS-CoV-2 on surfaces. J Infect Dis. 2020;222(2):214-22. https://www.ncbi.nlm.nih.gov/pubmed/32432672

16. Nicas M, Sun G. An integrated model of infection risk in a health-care environment. Risk Anal. 2006;26(4):1085-96. https://www.ncbi.nlm.nih.gov/pubmed/16948699

17. Judson SD, Munster VJ. Nosocomial transmission of emerging viruses via aerosol-generating medical procedures. Viruses. 2019;11(10). https://www.ncbi.nlm.nih.gov/pubmed/31614743

18. Tellier R, Li Y, Cowling BJ, Tang JW. Recognition of aerosol transmission of infectious agents: a commentary. BMC Infect Dis. 2019;19(1):101. https://www.ncbi.nlm.nih.gov/pubmed/30704406

19. Beacon TH, Su RC, Lakowski TM, Delcuve GP, Davie JR. SARS-CoV-2 multifaceted interaction with the human host. Part II: Innate immunity response, immunopathology, and epigenetics. IUBMB Life. 2020. https://www.ncbi.nlm.nih.gov/pubmed/32936531

20. WHO. Transmission of SARS-CoV-2: implications for infection prevention precautions.; 2020 9 July 2020. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

21. Chia PY, Coleman, K. K., Tan, Y. K., Ong, S. W. X., Gum, M., Lau, S. K., Sutjipto, S., et al. Detection of air and surface contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in hospital rooms of infection patients. medRxiv preprint. 2020. https://doi.org/10.1101/2020.03.29.20046557

22. Guo ZD, Wang ZY, Zhang SF, Li X, Li L, Li C, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. Emerg Infect Dis. 2020;26(7). https://www.ncbi.nlm.nih.gov/pubmed/32275497

23. van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med. 2020;382(16):1564-7. https://www.ncbi.nlm.nih.gov/pubmed/32182409

24. Qian H, Miao, T., Liu, L., Zheng, X., Luo, D., Li, Y. Indoor transmission of SARS-CoV-2. medRxiv preprint. 2020. https://www.medrxiv.org/content/10.1101/2020.04.04.20053058v1.full.pdf

25. McMichael TM, Currie DW, Clark S, Pogosjans S, Kay M, Schwartz NG, et al. Epidemiology of Covid-19 in a long-term care facility in King County, Washington. N Engl J Med. 2020;21:2005-11. https://www.ncbi.nlm.nih.gov/pubmed/32220208

26. Lai CC, Wang JH, Ko WC, Yen MY, Lu MC, Lee CM, et al. COVID-19 in long-term care facilities: An upcoming threat that cannot be ignored. J Microbiol Immunol Infect. 2020;53:444-6. https://www.ncbi.nlm.nih.gov/pubmed/32303483

27. Mallapaty S. What the cruise-ship outbreaks reveal about COVID-19. Nature. 2020;580(7801):18. https://www.ncbi.nlm.nih.gov/pubmed/32218546

28. Dyal JW, Grant MP, Broadwater K, Bjork A, Waltenburg MA, Gibbins JD, et al. COVID-19 Among Workers in Meat and Poultry Processing Facilities - 19 States, April 2020. MMWR Morb Mortal Wkly Rep. 2020;69(18):557–61. https://www.ncbi.nlm.nih.gov/pubmed/32379731

29. Zhang S, Diao M, Yu W, Pei L, Lin Z, Chen D. Estimation of the reproductive number of novel coronavirus (COVID-19) and the probable outbreak size on the Diamond Princess cruise ship: A data-driven analysis. Int J Infect Dis. 2020;93:201-4. https://www.ncbi.nlm.nih.gov/pubmed/32097725

30. Luo L, Liu, D., Liao, X., Wu, X., Jing, Q., Zheng, J.,, Liu, F., et al. Modes of contact and risk of transission in COVID-19 among close contacts. medRxiv preprint. 2020. https://doi.org/10.1101/2020.03.24.20042606

31. Nardell EA. Indoor environmental control of tuberculosis and other airborne infections. Indoor Air. 2016;26(1):79-87. https://www.ncbi.nlm.nih.gov/pubmed/26178270

32. WHO. Report of the WHO-China Joint Mission on Coronvirus Disease 2019 (COVID-19). 2020 February 16-24 2020. https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf

33. Verity R, Okell LC, Dorigatti I, Winskill P, Whittaker C, Imai N, et al. Estimates of the severity of coronavirus disease 2019: a model-based analysis. Lancet Infect Dis. 2020;20(6):669-77. https://www.ncbi.nlm.nih.gov/pubmed/32240634

34. Lu J, Gu J, Li K, Xu C, Su W, Lai Z, et al. COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020. Emerg Infect Dis. 2020;26(7):1628-31. https://www.ncbi.nlm.nih.gov/pubmed/32240078

35. Tang JW, Bahnfleth WP, Bluyssen PM, Buonanno G, Jimenez JL, Kurnitski J, et al. Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus (SARS-CoV-2). J Hosp Infect. 2021. https://www.ncbi.nlm.nih.gov/pubmed/33453351

36. Tellier R. Review of aerosol transmission of influenza A virus. Emerg Infect Dis. 2006;12(11):1657-62. https://www.ncbi.nlm.nih.gov/pubmed/17283614

37. Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. PLoS One. 2012;7(4):e35797. https://www.ncbi.nlm.nih.gov/pubmed/22563403

38. Kori N, Periyasamy P, Ng BH, Satariah Ali UK, Zainol Rashid NZ. Aerosolised COVID-19 transmission risk: surgical or N95 Masks? Infect Control Hosp Epidemiol. 2020:1-8. https://www.ncbi.nlm.nih.gov/pubmed/32928321

39. Lewis D. Is the coronavirus airborne? Experts can't agree. Nature. 2020;580(7802):175. https://www.ncbi.nlm.nih.gov/pubmed/32242113

40. Gaglia M, Lakdawala, S. What we do and do not know about COVID-19’s infectious disea and viral load. The Conversation. 2020. https://theconversation.com/what-we-do-and-do-not-know-about-covid-19s-infectious-dose-and-viral-load-135991

41. Wikramaratna P, Paton, R. S., Ghafari, M., Lourenco, J. Estimating false-negative detetion rate of SARS-CoV-2 by RT-PCR. medRxiv preprint. 2020. https://doi.org/10.1101/2020.04.05.20053355.

42. Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z, et al. SARS-CoV-2 viral load in upper respiratory specimens of infected patients. N Engl J Med. 2020;382(12):1177-9. https://www.ncbi.nlm.nih.gov/pubmed/32074444

43. Pan Y, Zhang D, Yang P, Poon LLM, Wang Q. Viral load of SARS-CoV-2 in clinical samples. Lancet Infect Dis. 2020;20(4):411-2. https://www.ncbi.nlm.nih.gov/pubmed/32105638

44. Hung IF, Cheng VC, Wu AK, Tang BS, Chan KH, Chu CM, et al. Viral loads in clinical specimens and SARS manifestations. Emerg Infect Dis. 2004;10(9):1550-7. https://www.ncbi.nlm.nih.gov/pubmed/15498155

45. Peiris JS, Chu CM, Cheng VC, Chan KS, Hung IF, Poon LL, et al. Clinical progression and viral load in a community outbreak of coronavirus-associated SARS pneumonia: a prospective study. Lancet. 2003;361(9371):1767-72. https://www.ncbi.nlm.nih.gov/pubmed/12781535

46. Davies NG, Abbott, R. C., Barnard, R. C., Jarvis, C. J. et al. Estimated transmissibility and severity of novel SARS-CoV-2 Variant of Concern 202012/01 in England.6 February 2021 https://cmmid.github.io/topics/covid19/uk-novel-variant.html

7. Lauring AS, Hodcroft EB. Genetic variants of SARS-CoV-2-what do they mean? JAMA. 2021. https://www.ncbi.nlm.nih.gov/pubmed/33404586

48. Leclerc QJ, Fuller NM, Knight LE, Group CC-W, Funk S, Knight GM. What settings have been linked to SARS-CoV-2 transmission clusters? Wellcome Open Res. 2020;5:83. https://www.ncbi.nlm.nih.gov/pubmed/32656368

49. Buising K, Williamson, D., Cowie, B., MacLachlan, J., Orr, L., MacIsaac, C., Williams, E., Bond, K., Muhi, S., McCarthy J., Maier, A. B., Irving, L., Heinjus, D., Kelly, C., Marshall, C. A hospital-wide response to multiple outbreaks of COVID-19 in health care workers. Lessons learned from the field. Med J Aust 2021;214:101-5. https://www.mja.com.au/journal/2021/214/3/hospital-wide-response-multiple-outbreaks-covid-19-health-care-workers-lessons

50. Meyerowitz EA, Richterman A, Gandhi RT, Sax PE. Transmission of SARS-CoV-2: A review of viral, host, and environmental factors. Ann Intern Med. 2021;174:69-79. https://www.ncbi.nlm.nih.gov/pubmed/32941052

51. Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, et al. Effectiveness of face masks in preventing airborne transmission of SARS-CoV-2. mSphere. 2020;5(5). https://www.ncbi.nlm.nih.gov/pubmed/33087517

52. Asadi S, Cappa CD, Barreda S, Wexler AS, Bouvier NM, Ristenpart WD. Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities. Sci Rep. 2020;10(1):15665. https://www.ncbi.nlm.nih.gov/pubmed/32973285

53. Chan JF, Yuan S, Zhang AJ, Poon VK, Chan CC, Lee AC, et al. Surgical mask partition reduces the risk of non-contact transmission in a golden Syrian hamster model for coronavirus disease 2019 (COVID-19). Clin Infect Dis. 2020; 71:2139-40. https://www.ncbi.nlm.nih.gov/pubmed/32472679

54. Oberg T, Brosseau LM. Surgical mask filter and fit performance. Am J Infect Control. 2008;36(4):276-82. https://www.ncbi.nlm.nih.gov/pubmed/18455048

55. Smith JD, MacDougall CC, Johnstone J, Copes RA, Schwartz B, Garber GE. Effectiveness of N95 respirators versus surgical masks in protecting health care workers from acute respiratory infection: a systematic review and meta-analysis. CMAJ. 2016;188(8):567-74. https://www.ncbi.nlm.nih.gov/pubmed/26952529

56. Bartoszko JJ, Farooqi MAM, Alhazzani W, Loeb M. Medical masks vs N95 respirators for preventing COVID-19 in healthcare workers: A systematic review and meta-analysis of randomized trials. Influenza Other Respir Viruses. 2020;14:365-73. https://www.ncbi.nlm.nih.gov/pubmed/32246890

57. Long Y, Hu T, Liu L, Chen R, Guo Q, Yang L, et al. Effectiveness of N95 respirators versus surgical masks against influenza: A systematic review and meta-analysis. J Evid Based Med. 2020;13:93-101. https://www.ncbi.nlm.nih.gov/pubmed/32167245

58. Greenlaugh T, Chan, X. H., Khunti, K., Durand-Moreau, Q., Straube, S., Devance, D., Toomey, E. What is the efficacy of standard face masks compared to respirator masks in preventing COVID-19-type respiratory illnesses in primary care staff? ; 2020 30 March, 2020. https://www.cebm.net/wp-content/uploads/2020/03/COVID-CAT-PPE-MASKS-9-REVISED-002.pdf

59. Conly J, Seto WH, Pittet D, Holmes A, Chu M, Hunter PR, et al. Use of medical face masks versus particulate respirators as a component of personal protective equipment for health care workers in the context of the COVID-19 pandemic. Antimicrob Resist Infect Control. 2020;9(1):126. https://www.ncbi.nlm.nih.gov/pubmed/32762735

60. Cevik M, Marcus JL, Buckee C, Smith TC. SARS-CoV-2 transmission dynamics should inform policy. Clin Infect Dis. 2020. https://www.ncbi.nlm.nih.gov/pubmed/32964919

61. Sommerstein R, Fux CA, Vuichard-Gysin D, Abbas M, Marschall J, Balmelli C, et al. Risk of SARS-CoV-2 transmission by aerosols, the rational use of masks, and protection of healthcare workers from COVID-19. Antimicrob Resist Infect Control. 2020;9(1):100. https://www.ncbi.nlm.nih.gov/pubmed/32631450

62. Raboud J, Shigayeva A, McGeer A, Bontovics E, Chapman M, Gravel D, et al. Risk factors for SARS transmission from patients requiring intubation: a multicentre investigation in Toronto, Canada. PLoS One. 2010;5(5):e10717. https://www.ncbi.nlm.nih.gov/pubmed/20502660

63. Loeb M, McGeer A, Henry B, Ofner M, Rose D, Hlywka T, et al. SARS among critical care nurses, Toronto. Emerg Infect Dis. 2004;10(2):251-5. https://www.ncbi.nlm.nih.gov/pubmed/15030692

64. Liu W, Tang, F., Fang, L-Q., de Vlas, S. J., Ma. H-J., Zhou, J-P., Looman, C. W. N. et al.. . Risk factors for SARS infection among hospital healthcare workers in Beijing: a case control study. Trop Med Int Health. 2009;14(Suppl. 1):52-9. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7169729/

65. WHO. Mask use in the context of COVID-19. 1 December 2020. https://www.who.int/publications-detail/advice-on-the-use-of-masks-in-the-community-during-home-care-and-in-healthcare-settings-in-the-context-of-the-novel-coronavirus-(2019-ncov)-outbreak

66. Public Health England. COVID-19: Guidance for maintaining services within health and care settings. January 2021 .https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/954690/Infection_Prevention_and_Control_Guidance_January_2021.pdf

67. European Centre for Disease Control. Infection prevention and control and preparedness for COVID-29 in healthcare settings.: Euopean CDC; 2020 3 July, 2020. https://www.ecdc.europa.eu/sites/default/files/documents/Infection-prevention-and-control-in-healthcare-settings-COVID-19_4th_update.pdf

68. Australian Health Protection Principal Committee. Guidance on the use of personal protective equipment (PPE) in hospitals during the COVID-19 outbreak. 12 November 2020. Guidance on the use of personal protective equipment (PPE) in hospitals during the COVID-19 outbreak

69. Hua W, Zuo Y, Wan R, Xiong L, Tang J, Zou L, et al. Short-term skin reactions following use of N95 respirators and medical masks. Contact Dermatitis. 2020;83(2):115-21. https://www.ncbi.nlm.nih.gov/pubmed/32406064

70. Wilkinson IJ, Pisaniello D, Ahmad J, Edwards S. Evaluation of a large-scale quantitative respirator-fit testing program for healthcare workers: survey results. Infect Control Hosp Epidemiol. 2010;31(9):918-25. https://www.ncbi.nlm.nih.gov/pubmed/20658919

71. Or P, Chung, J., Wong, T. Does training in performing a fit check enhance N95 respirator efficacy? Workplace Helalth and Safety. 2012;60(12):511-5. https://journals.sagepub.com/doi/pdf/10.1177/216507991206001202