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Infection Prevention during the Coronavirus Disease 2019 Pandemic

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BACKGROUND AND EPIDEMIOLOGY

In December 2019 a cluster of cases of pneumonia of unclear etiology was identified in Wuhan, Hubei Province, China. Evidence from the initial cases suggested a link with exposures at a local seafood market; however, this association waned over time and clear evidence of person-to-person transmission emerged.1,2 The etiologic agent was identified to be a novel human betacoronavirus subsequently named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the clinical disease was named coronavirus disease 2019 (COVID-19).3,4 Other epidemic coronaviruses have contributed to significant outbreaks in the recent past, although on a much smaller scale compared with SARS-CoV-2. The initial severe acute respiratory syndrome...

KEYWORDS

- COVID-19
- SARS-CoV-2
- Coronavirus
- Infection prevention
- Epidemiology
- Transmission
- Personal protective equipment
- Public health

KEY POINTS

- Cases of COVID-19, a nonspecific viral infection caused by the novel coronavirus SARS-CoV-2, were first identified in Wuhan, China, in December 2019 and led to an ongoing global pandemic.
- Transmission is primarily human-to-human via contact with respiratory particles containing infectious virus.
- The risk of transmission to health care personnel is low with proper use of personal protective equipment, including gowns, gloves, N95 or surgical mask, and eye protection.
- Additional important measures to decrease the risk of transmission include physical distancing, hand hygiene, routine cleaning and disinfection, and appropriate air handling and ventilation.
- Public health interventions, including universal masking, stay-at-home orders, and other mitigation strategies, are effective at decreasing transmission rates.
(SARS) outbreak caused by SARS-associated coronavirus (SARS-CoV) occurred from 2002 to 2003 and caused 8096 cases in 29 countries, with an overall case fatality ratio of 9.6%. Early on during the COVID-19 pandemic, many recommendations were extrapolated from experience from the SARS pandemic and other epidemic respiratory viral infections.\(^5,6\) Cases of Middle East respiratory syndrome coronavirus (MERS-CoV) have been identified in 27 countries since 2012, with an overall case fatality ratio of 35%.\(^7\) The SARS-CoV-2 outbreak quickly developed into a widespread global pandemic, with more than 250,000,000 cases and 5 million deaths worldwide.\(^8\)

**CLINICAL MANIFESTATIONS AND OUTCOMES**

Despite accounting for approximately 22% of the population in the United States, children younger than 18 represent a minority of COVID-19 cases (12.4%), hospitalizations (1.6%), and related deaths (0.1%) diagnosed in the United States.\(^9\)\(^-\)\(^11\) COVID-19–associated hospitalization rates are lower in pediatric patients than adults; approximately 2.5% of children and young adults with COVID-19 require hospitalization compared with 16.6% of adults.\(^12\) The most common comorbidities in hospitalized patients with COVID-19 include hypertension, obesity, diabetes, chronic lung disease, and prematurity.\(^12\)\(^-\)\(^15\) The estimated case fatality ratio is as high as 1.8% to 7.2%, with increasing mortality rates in increasing age brackets.\(^14\)\(^-\)\(^16\) COVID-19–related deaths are rare in children (<0.1% of COVID-19 cases) compared with 5% in adults, with increasing mortality rates in adults every decade after age 25.\(^10\)\(^,\)\(^12\)\(^,\)\(^17\)

Perinatal infection is rare, indeed 2.6% of infants born to mothers with laboratory-confirmed COVID-19 at the time of delivery who were tested had positive SARS-CoV-2 testing.\(^18\) To date, definitive evidence of intrauterine transmission of SARS-CoV-2 from mother to infant has not been confirmed.\(^19\)

Multisystem inflammatory syndrome in children (MIS-C) is a hyper inflammatory condition with features similar to Kawasaki disease and toxic shock syndrome, which has been seen approximately 2 to 4 weeks after acute COVID-19 infection in children. Presenting features include shock, cardiac dysfunction, gastrointestinal symptoms (abdominal pain, vomiting, diarrhea), elevated inflammatory markers, rash, mucocutaneous involvement, and positive polymerase chain reaction (PCR) or antibody testing for SARS-CoV-2. Treatment typically includes intravenous immune globulin with or without antiplatelet/anticoagulant medications and additional immunomodulatory agents.\(^20\)

Meta-analyses demonstrated that 16% to 19% of pediatric patients and 17% of adults with COVID-19 are asymptomatic.\(^21\)\(^-\)\(^23\) A meta-analysis including 67 studies with 8302 adult and pediatric patients demonstrated that fever and cough are the most common manifestations in pediatric and adult patients (**Table 1**); however, symptoms differed in adults and children, with fever (69% vs 44%), cough (53% vs 33%), and dyspnea (20% vs 4%) more common among adult patients compared with pediatric patients.\(^24\)

**REPRODUCTIVE NUMBER AND SECONDARY ATTACK RATE FOR SEVERE ACUTE RESPIRATORY SYNDROME CORONAVIRUS 2**

The estimated reproductive number ($R_0$) represents the average number of secondary infections from an index case in a susceptible population.\(^4\) The $R_0$ from analysis of the first 425 patients with confirmed COVID-19 in Wuhan, China, was 2.2 and review of 12 studies estimated the mean $R_0$ to be 3.28 and the median 2.79.\(^2\)\(^,\)\(^25\) These estimates reflect transmission early on during the pandemic (through January 2020) before detection of variants of concern. In comparison, the median $R_0$ for seasonal influenza
is 1.28, 1.46 for the 2009 H1N1 influenza epidemic, and 1.80 for the 1918 influenza pandemic.\textsuperscript{26}

In the pre-vaccine era, the secondary attack rate, or proportion of susceptible individuals who acquire COVID-19 after exposure, varied with the setting. A systematic review and meta-analysis including 43 studies found a pooled secondary attack rate among household contacts of 18.1\%, ranging from 3.9\% to 54.9\%.\textsuperscript{27} Variable attack rates were seen in nonhousehold, non–health care settings, ranging from 0\% to 5.8\% in larger studies (with >1000 contacts).\textsuperscript{27} In comparison the estimated household secondary attack rates for 2009 H1N1 influenza epidemic ranged from 8\% to 19\%.\textsuperscript{28} Secondary attack rates for selected pathogens transmitted via an airborne route include 90\% for measles and 85\% for varicella.\textsuperscript{29,30}

\begin{table}
\centering
\begin{tabular}{|l|c|c|}
\hline
\textbf{Manifestation} & \textbf{Pediatric, \%}\textsuperscript{21,23,24} & \textbf{Adult, \%}\textsuperscript{22,24} \\
\hline
Asymptomatic & 16–19 & 17 \\
Fever & 44–57 & 69 \\
Cough & 33–44 & 53 \\
Dyspnea & 4–15 & 20 \\
Rhinorrhea & 13–16 & 13 \\
Diarrhea & 10–12 & 9 \\
Nausea/vomiting & 9–11 & 8 \\
Headache & 10–13 & 19 \\
Sore throat & 8–14 & 18 \\
Nasal congestion & 9 & 26 \\
Abdominal pain & 6–8 & Not reported \\
Fatigue & 6–9 & 31 \\
Myalgias & 5–14 & Not reported \\
Anosmia & 4 & 38 \\
\hline
\end{tabular}
\caption{Clinical manifestations of adult and pediatric patients with coronavirus disease 2019}
\end{table}

\textit{Data from Refs.}\textsuperscript{21–24}

TRANSMISSION

The median incubation period for SARS-CoV-2 is estimated to be 5 days. More than 95\% of people develop symptoms within approximately 12 days after exposure and there is a low likelihood of symptomatic infections developing after 14 days.\textsuperscript{2,31}

The first documented case of person-to-person transmission of SARS-CoV-2 in the United States involved the spouse of a returning traveler from Wuhan, China.\textsuperscript{1} Initial concepts regarding transmission of SARS-CoV-2 were drawn from experience during the original 2003 SARS epidemic, where peak infectiousness occurred 7 to 10 days after symptom onset.\textsuperscript{32} However, reports of asymptomatic and more commonly pre-symptomatic transmission quickly emerged,\textsuperscript{32–34} including evidence of person-to-person transmission during the pre-symptomatic phase and from fully asymptomatic individuals.\textsuperscript{35,36} Approximately 44\% of secondary cases were attributed to exposures during the pre-symptomatic stage of index cases, with the period of peak infectiousness extending from 2 days before symptom onset through 1 day after symptom onset.\textsuperscript{32} High viral loads have been detected in the nasopharynx/oropharynx
during the first week of symptoms, with peak viral loads demonstrated on day 4 of symptoms, and a decline over time.\textsuperscript{37–39}

AIRBORNE VERSUS DROPLET

The classic distinction is between large (>5 μm) respiratory droplets, which travel up to 3 to 6 feet from the source and then fall to the ground or another surface and airborne particles known as aerosols, which are tiny (≤5 μm), and may remain suspended in the air for extended periods of time and travel greater distances.\textsuperscript{40} Examples of pathogens transmitted primarily via large respiratory droplets include influenza, seasonal human coronaviruses, and many other respiratory viral pathogens. Measles and varicella are classic examples of viruses transmitted via an airborne route. The distinction between these 2 forms of transmission is critical to inform appropriate personal protective equipment (PPE) recommendations for health care personnel (HCP); specifically N95 respirators or equivalent are recommended to prevent transmission of airborne pathogens because tiny aerosols are not adequately filtered by isolation/surgical masks. In addition, 3 to 6 feet of physical distancing and/or surgical masks would not prevent transmission of aerosols via an airborne route, but would interrupt transmission of large respiratory droplets.\textsuperscript{41–43} However, individuals generate droplets and aerosols of varying sizes that can travel distances greater than 6 feet, and transmission risk may be higher in crowded indoor environments, particularly those with poor ventilation.\textsuperscript{43}

This dichotomy between respiratory droplet and aerosol/airborne transmission likely represents an oversimplification and does not solely define or adequately explain viral transmission risk.\textsuperscript{44} Contributing to confusion surrounding this subject, terminology including airborne particles, aerosols, and droplets may be interpreted differently by infection prevention specialists and aerobiologists.\textsuperscript{44} Additional factors determining transmission risk to an individual after exposure include the viral burden in the source, environment including ventilation, conditions surrounding the exposure including route and duration, inoculum size, host factors, and PPE use.\textsuperscript{41,44}

SARS-CoV-2 has been detected by PCR in air samples from patient rooms and other areas of acute care hospitals during the COVID-19 pandemic,\textsuperscript{45–47} raising the possibility of airborne transmission. In experimental models, SARS-CoV-2 remained stable in generated aerosols for 3 hours.\textsuperscript{48} Increased transmission risk of SARS has been associated with selected aerosol-generating procedures (AGPs), including tracheal intubation, noninvasive ventilation, tracheotomy, and manual ventilation before intubation, with tracheal intubation consistently identified across multiple studies.\textsuperscript{49} Thus AGPs carry additional risk of airborne transmission of aerosols containing SARS-CoV-2.

List of AGPs adapted from Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) guidance:

- Open suctioning of airways
- Sputum induction (using nebulized hypertonic saline)
- Cardiopulmonary resuscitation
- Endotracheal intubation and extubation
- Noninvasive ventilation (eg, bilevel positive airway pressure, continuous positive airway pressure)
- Bronchoscopy
- Manual ventilation (including before intubation)
- Tracheotomy
- Autopsy procedures
• Based on available data, it is unclear whether aerosols generated from the following procedures are infectious:
  ◦ Nebulizer administration
  ◦ High flow oxygen delivery\textsuperscript{50,51}

**SPECIFIC SCENARIOS OF CONCERN**

**Restaurant with Poor Ventilation**

Nine individuals from 3 families who dined at adjacent tables in the same restaurant developed COVID-19. No infections were identified in restaurants staff or diners at other tables in the restaurant. All 5 secondary cases in the other 2 families were separated from the index case by more than 1 m, and poor ventilation in the restaurant (0.56–0.77 air changes per hour) was identified as a potential contributing factor.\textsuperscript{52}

**Cruise Ships**

Outbreaks on cruise ships were associated with high transmission rates; 19.2\% of passengers and crew on the Diamond Princess had positive SARS-CoV-2 testing, 16.6\% on the Grand Princess.\textsuperscript{53}

**Singing/Choir Practice**

Of 61 individuals who attended a 2.5-hour choir practice where 1 person was known to be symptomatic, 33 confirmed cases and 20 probable cases were identified. This represents a secondary attack rate of 53.3\% for confirmed cases and 86.7\% for confirmed and suspected cases, suggesting the possibility of a superspreader event at the choir practice.\textsuperscript{54}

**Religious Services**

Following exposure at various church events over a 6-day period, 38\% of the 92 attendees developed COVID-19.\textsuperscript{55}

**Homeless Shelters**

High SARS-CoV-2 prevalence has been identified among residents of homeless shelters. In 1 study from 19 homeless shelters in 4 US cities, 25\% of residents tested positive, with a range of 4\% to 66\% at each individual shelter.\textsuperscript{56}

**Overnight Camp**

Of 597 campers and staff who attended an overnight summer camp in Georgia where masking was not required for campers and building windows and doors were not opened for ventilation, the attack rate was 44\%.\textsuperscript{57}

**IMPACT OF SUPPLY CHAIN**

Global shortages of medical supplies, including PPE such as N95s, necessitated the development of allocation and prioritization strategies for the judicious use of scarce resources.\textsuperscript{58} Many hospitals experienced critical shortages of respirators, surgical masks, gowns, gloves, and eye coverings, and therefore implemented extended use of masks/respirators, reprocessing of respirators, extended use or reuse of gowns, and sometimes self-production of PPE, such as eye protection, masks, and gowns. Ethical guidance regarding PPE optimization strategies, COVID-19 therapeutics, patient triaged, and visitor policies were provided to many health care facilities by local institutions, states, and professional organizations.\textsuperscript{59}
Based on the scarce supply and availability of N95 or equivalent respirators, the CDC provided recommendations, including extended use and limited reuse of N95 respirators beyond the manufacturer recommendations. In addition, in the setting of critical supply shortages, the CDC recommends prioritization of N95 respirators or equivalent for HCP with the highest risk potential exposures, specifically being present in the room with a patient with COVID-19 undergoing an AGP. Engineering controls, such as the addition of portable high-efficiency particulate air (HEPA) filtration devices, also can be considered.

As a result, many health care institutions implemented a risk-stratified approach for patients with known or suspected COVID-19 whereby N95 respirators or equivalent were recommended during care of patients with confirmed or suspected COVID-19 undergoing AGP, whereas surgical masks or N95 respirators or the equivalent were appropriate for patients not undergoing AGP. Most health care facilities that responded to a survey through the Society for Healthcare Epidemiology of America Research Network recommended that HCP wear an N95 respirator or equivalent for patients with confirmed or suspected COVID-19 undergoing higher-risk AGP, including intubation and extubation, as well as for ear, nose, and throat procedures and other procedures of the airway/respiratory tract.

**TRANSMISSION TO HEALTH CARE PROVIDERS**

Across varying populations, the overall risk of SARS-CoV-2 transmission was low, ranging from 0.9% to 7.0% (Table 2). A systematic review and meta-analysis including 18 studies found an estimated secondary attack rate of 0.7% in the health care setting.

**EXPOSURE SOURCE AND SETTING**

Identified HCP exposure sources were variable, with 55% to 59% in the health care setting, 13% to 27% in the community/household setting, and 5% to 13% with exposures in multiple settings. Among health care setting exposures, contact with patients (63%) or colleagues with COVID-19 (31%) were the most common identified sources. HCP with SARS-CoV-2 exposures from household or social contacts had the highest positivity rate. Higher-risk exposures and HCP COVID-19 infections were seen most commonly among nursing assistants/patient care aides (32%–40%) and nursing staff (30%), and occurred most often during direct patient care (66%). Factors associated with transmission to HCPs included performing physical examinations and presence in the room during AGPs; longer estimated time in the patient’s room may also play a role. HCPs working in congregate living, long-term care, or nursing/residential care facilities were more likely to acquire COVID-19 than HCPs working in an acute care setting. However, this may in part be impacted by relative PPE use because HCPs in the acute and ambulatory care setting were more likely than those in the congregate living or long-term care setting to wear masks (83% vs 62%) and eye protection (26% vs 16%).

Interestingly, in a study among 336 active duty military personnel deployed to a field hospital with strict infection prevention measures in place, 1.7% developed COVID-19; infection rates were lower in those who provided direct care to COVID-19 patients (0.9%). The military personnel had continual donning and doffing observation with assistance and wore N95 respirators, eye protection, gowns, gloves, and gowns during patient care. The military personnel stayed in single-occupancy rooms at local hotels and were encouraged by the military chain of command to remain in their hotel room as much as possible. Taken as a whole, these data suggest that the risk of
| Study                        | Dates                  | Setting                          | Sample Size | Attack Rate, % | Miscellaneous                                      |
|------------------------------|------------------------|----------------------------------|-------------|----------------|---------------------------------------------------|
| Wang et al,61 2020           | December 2019–March 2020 | China                            | 5442        | 2.2            | All enrolled and tested                            |
| Lai et al,62 2020            | January–February 2020   | China                            | 9684        | 1.1            | 0.7% of 335 randomly selected asymptomatic HCP tested positive |
| Kluytmans-van den Bergh et al,63 2020 | March 2020 | Netherlands                     | 9705        | 1              | 6.4% of 1353 tested due to development of symptoms tested positive |
| Clifton et al,64 2020        | March–April 2020        | US army personnel                | 336         | 1.7            | All enrolled and tested, 2 PCR+, 5 Ab+, 1 both+    |
| Fell et al,65 2020           | March–July 2020         | US                               | 5374        | 7%             | All with higher-risk exposures (household/workplace) |
| Self et al,66 2020           | April–June 2020         | US seroprevalence study          | 3248        | 6              | All enrolled and tested (serology)                 |
| Shah et al,67 2021           | May–November 2020       | United States                    | 345         | 2.3            | All with significant occupational exposure to a COVID-19 patient |
| Koh et al,27 2020            | January–July 2020       | China, United States, Germany, India, Japan, Singapore, Switzerland | 4163 | 0.7 | Systematic review and meta-analysis of 18 studies |

**Abbreviations:** Ab, antibody; COVID-19, coronavirus disease 2019; HCP, health care provider; PCR, polymerase chain reaction.

*Data fromRefs.27,61–67*
SARS-CoV-2 transmission to HCPs wearing appropriate PPE during patient care is low, and that exposures outside the workplace also play an important role in transmission risk to HCP.

PERSONAL PROTECTIVE EQUIPMENT EFFICACY

Experimental Data

Experimental studies have demonstrated that face coverings are highly effective forms of source control, specifically hospital-grade surgical masks provide a 94% reduction in respiratory droplet particle concentration when used as source control, N95 respirators provide a 95% reduction, and cloth face coverings provide a 77% reduction.71

Health Care Setting: Other Viruses

A systematic review of interventions to reduce or prevent transmission of respiratory viral pathogens demonstrated that frequent hand hygiene, wearing masks including N95s, wearing gowns, and wearing gloves were all associated with decreased risk of SARS transmission with a 91% effectiveness and number needed to treat of 3 for the combination of hand hygiene, masks, gowns, and gloves.72

A meta-analysis of 4 randomized controlled trials comparing the protective effect of medical masks to N95 respirators in HCPs, which included influenza, SARS, and seasonal human coronaviruses, but not SARS-CoV-2, showed no difference in the incidence of laboratory-confirmed viral respiratory infections or clinical respiratory illnesses.73

Health Care Setting: Severe Acute Respiratory Syndrome Coronavirus 2

In a systematic review and meta-analysis including 44 comparator studies evaluating the risk of person-to-person transmission of SARS-CoV-2, SARS, and MERS, physical distancing of at least 1 m, wearing face masks, and wearing eye protection were all independently associated with a decreased risk of transmission. Of note, only 7 of these studies evaluated SARS-CoV-2 transmission, the remainder evaluated SARS or MERS transmission.74

A systematic review and meta-analysis evaluating airborne transmission and the role of face masks for prevention of SARS-CoV-2 transmission identified 4 studies with 7688 participants in demonstrated decreased risk of SARS-CoV-2 infection with face masks, including N95s (RR 0.12).75

A retrospective study from January 2020 at a single center in Wuhan, China, found that HCPs working in units where no masks were worn and standard hand hygiene practices occurred were more likely to develop COVID-19 than HCPs working in units where N95 respirators were worn and frequent hand hygiene was performed (adjusted odds ratio [aOR] 464.8).76

In review of HCP infections that occurred early on during the pandemic in Hubei Province, China, during a time when many HCPs were not yet wearing recommended PPE when caring for patients with possible COVID-19, the relative risk of HCP infection was 36.9 times higher in those who did not wear appropriate PPE compared with those who did. Only 0.08% (1 of 1287) staff members became infected while wearing appropriate PPE.51

In a review of 345 HCPs with an occupational exposure to a patient with COVID-19, lack of eye protection during the exposure was associated with an increased risk of SARS-CoV-2 transmission to the HCP (Risk Ratio 14.1, 95% confidence interval 1.3–150.1).67
Non–Health Care Settings

Real-world scenarios have also demonstrated the efficacy of masks/face coverings in preventing SARS-CoV-2 transmission both through source control and protection to the wearer. A well-reported example describes the experience of 2 hairstylists who both worked with symptomatic COVID-19. Despite transmission from one hairstylist to the other and to close contacts in their household where there were unmasked exposures, no secondary cases resulted from encounters with any of the 139 clients during which the hairstylists and clients were masked.77

A retrospective case-control study from Thailand comparing 211 exposed individuals who developed COVID-19 with 839 exposed individuals who did not develop COVID-19 showed that wearing masks all the time during the contact period was independently associated with decreased risk of COVID-19 infection (aOR 0.23). Maintaining of physical distance of greater than 1 m from the exposure source (aOR 0.15), duration of close contact ≤15 minutes (aOR 0.24), and frequent hand hygiene (aOR 0.33) were also associated with a decreased risk of infection.78

CENTERS FOR DISEASE CONTROL AND PREVENTION RECOMMENDATIONS FOR HEALTH CARE FACILITIES DURING THE CORONAVIRUS DISEASE 2019 PANDEMIC

Universal Masking

Well-fitting surgical masks, isolation masks, cloth masks, or respirators that cover the mouth and nose are recommended as a form of universal source control as well as protection to the wearer within health care facilities. Masks are not recommended for children younger than 2 or any individuals with an underlying disability or medical condition that prevents them from safely wearing a face mask.

Physical Distancing

When possible, physical distancing of at least 6 feet between people is an important measure in preventing transmission of SARS-CoV-2. Important considerations that enable physical distancing include limiting visitors to health care facilities, scheduling appointments to limit the number of individuals in waiting rooms, arranging seating in waiting rooms and other common area as so individuals may remain 6 feet apart, and modifying in-person visits through the use of virtual communication devices.

Attention to Non–Patient-Care Areas

Importantly, clusters of transmission between HCPs have been described, particularly related to the lack of universal masking and/or physical distancing between colleagues. It is critical that measures including universal masking and physical distancing are followed in non–patient care workspaces throughout health care facilities. Dedicated areas for HCPs to remain physically distanced during breaks or when eating and/or drinking should be identified to promote a safe working environment and minimize exposure risk during these times when HCPs are unmasked.

Exposure Follow-Up and Contact Tracing

In partnership with occupational health and infection prevention experts, health care facilities should design a process to follow up COVID-19 cases, identify potential exposures, and perform contact tracing and other associated follow-up. This should occur promptly after a case is identified and ensures the privacy of patients, visitors, and HCPs. This process should also incorporate notification of the local public health department.
PERSONAL PROTECTIVE EQUIPMENT AND PATIENT CARE

In addition to universal masking, standard precautions, and transmission-based precautions, the CDC recommends the following in areas of moderate to high SARS-CoV-2 transmission during all patient care:

- N95 or equivalent respirators should be used during all AGPs.
- Eye protection should be worn during patient care to protect the eyes from possible exposure to respiratory secretions.

The CDC recommends the following Infection Prevention practices during the care of a patient with suspected or confirmed COVID-19:

- The patient should be cared for in a single-occupancy room with a dedicated bathroom when possible.
- Airborne infection isolation rooms with the door closed are recommended for patients with suspected or confirmed COVID-19 who are undergoing AGP.
  - Facilities should monitor the negative pressure relationship of these rooms.
- Dedicated HCPs on a dedicated unit should be considered for the care of patients with suspected or confirmed COVID-19 as a measure to limit personnel exposures and conserve PPE.
- Patient transports and other movement throughout the health care facility should be minimized, and patients should wear a face covering during transport.
- HCPs should perform hand hygiene before donning PPE, before and after patient contact, after doffing PPE, and during the other recommended scenarios as described in WHO’s 5 moments of hand hygiene.\(^7^9\)
- Training on the indications for PPE use as well as appropriate donning and doffing instruction should be provided to all personnel to maximize protection and minimize the risk of self-contamination.

The CDC recommends that HCPs and other personnel entering the room of patients with suspected or confirmed COVID-19 should don the following PPE:

- N95 or equivalent respirator (during N95 or equivalent respirator shortages, respirators should be prioritized for patients requiring airborne precautions\(^8^0\))
- Gown
- Gloves
- Eye protection

INFECTIOUS DISEASES SOCIETY OF AMERICA RECOMMENDATIONS

Infectious Diseases Society of America guidelines on infection prevention for HCPs caring for patients with confirmed or suspected COVID-19 recommend N95 respirators or equivalent (in addition to gowns, gloves, and eye protection) for patients undergoing AGPs. A surgical mask or N95 or equivalent respirator is recommended for patients with COVID-19 who are not undergoing an AGP.\(^8^1\)

Duration of Isolation Precautions

Early on during the pandemic, a test-based strategy was recommended to discontinue transmission-based precautions for patients with COVID-19. However, despite prolonged detection of SARS-CoV-2 virus by PCR, isolation of live, replication-competent virus has not been detected after 8 to 10 days and has been rarely detected up to 20 days in immunocompromised individuals or in individuals with severe infections.\(^3^8,^8^2,^8^3\) Exposure to an index case after day 5 of symptoms was not
associated with SARS-CoV-2 transmission in a large contact-tracing study. In addition, in a study of persistently positive patients, no secondary infections were identified among close contacts, and viable virus was not detected in culture for patients with repeat positive PCR tests.

Based on these data and other emerging evidence, use of a symptom-based strategy to discontinue transmission-based precautions was subsequently recommended. Current CDC guidance recommends the following criteria to discontinue precautions for patients with COVID-19 in health care settings.

For patients with mild to moderate illness who are not severely immunocompromised:

- At least 10 days have passed since symptoms first appeared, and
- At least 24 hours have passed since the last fever without the use of antipyretics, and
- Symptoms have improved

For asymptomatic patients who are not severely immunocompromised:

- At least 10 days have passed since the collection date of the first positive viral test

For patients with severe to critical illness or who are severely immunocompromised:

- At least 10 days and up to 20 days have passed since symptoms first appeared, and
- At least 24 hours have passed since the last fever without the use of antipyretics, and
- Symptoms have improved, and
- Consider consultation with infection prevention experts

HAND HYGIENE, ENVIRONMENT OF CARE/CLEANING, AND ENGINEERING CONTROLS

Experimental data have demonstrated that SARS-CoV-2 is effectively inactivated by WHO-recommended alcohol-based hand rub formulations. In addition, evidence has shown that frequent hand hygiene in conjunction with other prevention strategies is associated with a decreased transmission risk of SARS-CoV-2 and other similar respiratory viruses to HCPs.

Other coronaviruses have been found to persist on environmental surfaces for up to 9 days. In experimental models, SARS-CoV-2 remained viable on hard surfaces for up to 72 hours after being applied and SARS-CoV-2 has been recovered after sampling environmental surfaces in COVID-19 patient rooms. Experimental evidence has demonstrated that SARS-CoV-2 is inactivated with routine cleaning and disinfection measures, including quaternary ammonium–containing products. In one study, environmental surfaces in COVID-19 patient rooms that were sampled after routine cleaning showed no detection of SARS-CoV-2, compared with 87% of surfaces sampled before routine cleaning with positive SARS-CoV-2 testing.

Because typical cleaning and disinfection measures are effective against the SARS-CoV-2 virus, the CDC recommends following routine practices for patient room cleaning, laundry, food service, and waste removal. Appropriate PPE should be worn by environmental services and other personnel during cleaning. Terminal cleaning after discharge should be delayed until an adequate number of air changes have occurred. Dedicated medical equipment should be used for the care of patients with suspected
or confirmed COVID-19 when possible. Any nondedicated equipment should be cleaned per manufacturer instructions for use and hospital policy.80

Engineering controls should be considered to minimize exposure within health care facilities. Examples include erecting physical barriers, establishing pathways to guide individuals through common areas, and minimizing the use of semiprivate rooms or open-bay lay-out patient care areas. In conjunction with facilities and engineering experts, steps to optimize air quality should be considered. For example, permanent air handling systems to control air pressure relationships, filtration, and air exchanges should be used where possible. The addition of portable solutions, such as HEPA filters, can be considered in areas where permanent air handling solutions are not possible. Ensuring appropriate room pressure relationships are present in patient care areas is also critical.50,80

SCREENING AND VISITATION

The CDC recommends limiting and monitoring entry points to health care facilities. Basic prevention measures include posting visual alerts with instructions about wearing masks or other face coverings, and the importance of hand hygiene. Alcohol-based hand sanitizer with at least 60% alcohol content should be readily available for use. The CDC also recommends screening all individuals, including HCPs, patients, and visitors, entering a health care facility for signs and symptoms of COVID-19, as well as exposures to anyone with COVID-19 in the past 14 days. Admitted patients also should be screened daily for fever and symptoms compatible with COVID-19. Once identified, basic source control measures should be enacted for individuals with suspected or confirmed COVID-19, including ensuring that the individual is wearing a mask, placing the patient in a private room with the door closed, restricting visitors from entering the facility, and excluding HCPs from work. Limitations of screening include not being able to identify asymptomatic or pre-symptomatic individuals, or individuals without known exposures. Unintended consequences of screening and restricting HCPs and visitors include excluding individuals with symptoms due to another cause, for example, an underlying health condition or allergic rhinitis.80 During the pandemic, the vast majority of health care facilities instituted screening for visitors and HCPs to detect the presence of fever and other symptoms of illness.59,92,93

PRE-PROCEDURAL TESTING

The CDC recommends that pre-admission and/or pre-procedure screening SARS-CoV-2 testing can be considered as an adjunctive measure to universal PPE and source control in health care settings. Important considerations include guidance from the local health department, testing availability and turnaround time, and local disease prevalence. Limitations of screening testing include identifying positive results in patients with prior infections who are no longer infectious but have prolonged PCR positivity, and potentially negative results due to testing during the incubation period or false negative results in the setting of an active infection due to limitations of the testing methodology.80

Many health care facilities routinely tested asymptomatic patients undergoing selected procedures, most commonly upper and lower airway procedures, labor and delivery, endoscopy, AGP, and sedation.59 Although PCR testing has most often been described for this indication, antigen testing may have a role as well. In a study of 386 asymptomatic adult patients undergoing pre-procedural testing, the negative predictive value of antigen testing compared with PCR was 99.2%.94
Across a variety of settings and patient populations, the prevalence of SARS-CoV-2 in patients tested for pre-procedural indications was low, ranging from 0.1% to 3.8% (Table 3). SARS-CoV-2 prevalence was lower in patients tested for pre-procedural indications compared with those who were tested due to exposure or clinical symptoms. In addition, percent positivity was lower in asymptomatic, vaccinated individuals undergoing pre-procedural testing compared with unvaccinated individuals.

Challenges with pre-procedural testing have also been identified. In one study, approximately half of patients either declined pre-procedural testing or could not be reached to arrange testing; barriers identified included lack of interest in testing, distance from testing facility, transport issues, and the patient’s perception of not being at risk for COVID-19. Positive pre-procedural SARS-CoV-2 testing was associated with delaying of the procedure by 29 days on average, with no COVID-19–related complications identified in any of the patients whether or not their procedure was delayed. Utility of a risk screening questionnaire to identify patients with positive pre-procedural SARS-CoV-2 testing remains unclear; in one study of 1000 patients undergoing endoscopy the negative predictive value of a validated risk screening questionnaire was 99.4%; however, the positive predictive value was only 2.5%

VISITATION

During the pandemic, the CDC recommended limiting visitation to those who are essential for the patient’s well-being and care, for example, parents and care partners. The use of virtual options for communication is encouraged. For patients with COVID-19, additional considerations surrounding visitation include evaluating the risk to the visitor, providing instruction on hand hygiene and use of PPE, restricting visitation during AGP, and restricting visitors to the patient’s room.

Most health care facilities permitted visitors for patients with suspected or confirmed COVID-19, at least under certain circumstances, especially during end-of-life care. Of those who permitted visitors for patients with confirmed or suspected COVID-19, 69% to 91% required visitors to wear PPE. For pediatric patients, 67% to 85% of health care facilities allowed 1 visitor per pediatric patient, and the remainder allowed 2. The vast majority (86%) did not permit visitors to leave the patient’s room. Most (74%) restricted visitors under a certain age, typically those younger than 18 years.

Visitor restrictions and other hospital-based measures implemented to minimize transmission risk in the health care setting posed unique challenges for pediatrics where parents/caregivers are critical members of the patient’s care team. For example, pandemic-related restrictions contributed to decreased parental presence at the bedside and participation in rounds in the neonatal intensive care unit setting. Important ancillary services, including therapy services, lactation, and social work support were also at least temporarily less widely available during the pandemic.

PUBLIC HEALTH MEASURES

The initial public health response included screening returning travelers from Wuhan, China, and on January 31, 2020, a presidential proclamation temporarily suspended entry for individuals who have visited China in the past 14 days. However, the yield of airport screening in identifying COVID-19 cases was low, with 0.001% or 1 case per 85,000 travelers screened testing positive for SARS-CoV-2.

Local masking mandates were associated with an increase in masking compliance in those areas and decreased SARS-CoV-2 transmission rates, associated
| Study                  | Dates                  | Setting/Population                                                                 | Sample Size (Patients) | Percent Positivity, % | Miscellaneous                                           |
|------------------------|------------------------|-----------------------------------------------------------------------------------|------------------------|-----------------------|---------------------------------------------------------|
| Lin et al, 95 2020     | March–April 2020       | US/Pediatric pre-procedural testing                                               | 1295                   | 0.9                   | Range of 0.2% to 2.7% across 3 hospitals                |
| Otto et al, 96 2020    | March–June 2020        | US/Pediatric pre-procedural and pre-admission testing                             | 1410                   | 3.8                   |                                                         |
| Aslam et al, 97 2020   | March–August 2020      | US/Cancer center pre-procedural testing                                           | 11,540                 | 0.6                   | Fell below 0.3% after April 2020                       |
| Bence et al, 98 2021   | March–October 2020     | US/Pediatric pre-procedural testing                                               | 11,150                 | 1.4                   |                                                         |
| Haidar et al, 99 2021  | April–June 2020        | US/Pre-procedural testing                                                         | 10,539                 | 0.1                   |                                                         |
| Bowyer et al, 100 2021 | May–June 2020          | US/Ambulatory pre-procedural testing before endoscopy                             | 1000                   | 0.8                   |                                                         |
| Larsen et al, 101 2021 | May–July 2020          | US/Ambulatory pre-procedural testing                                              | 3709                   | 1                     |                                                         |
| Tande et al, 102 2021  | December 2020–February 2021 | US/Pre-procedural testing                                                    | 39,156                 | 3.1                   |                                                         |

Data from Refs. 95–102
hospitalizations, and deaths. Masking compliance varies based on age, sex, geographic setting, location of activity, and political affiliation.

Stay-at-home orders and other public health mitigation strategies are also effective at decreasing local SARS-CoV-2 transmission rates, with evidence of decreased mortality rates in areas with more stringent mitigation policies.

Although efficient and early contact tracing can be an effective component in controlling SARS-CoV-2 outbreaks, challenges in identifying and notifying contacts in a timely manner, particularly after increasing caseloads, resulted in discontinuation of contact-tracing efforts by a local health department agencies.

Before widespread vaccine availability, recommended public health strategies to prevent ongoing SARS-CoV-2 transmission included the following:

- Universal face covering
- Physical distancing
- Limiting contacts with persons outside your bubble
- Avoiding nonessential indoor spaces and crowded outdoor settings
- Increasing testing to promptly diagnosis and initiate isolation
- Prompt case investigation and contact tracing
- Protecting essential workers and persons at high risk for severe illness, complications, and death
- Postponing travel
- Increasing room air ventilation
- Increased hand hygiene and cleaning/disinfection
- Widespread vaccine coverage

**CLINICS CARE POINTS**

- SARS-Cov-2 transmission risk in the healthcare setting can be mitigated by proper use of personal protective equipment, including gowns, gloves, N95 or surgical mask, and eye protection.
- Additional strategies such as physical distancing, hand hygiene, routine cleaning and disinfection, appropriate air handling and ventilation, and public health interventions are also important tools to minimize transmission risk of SARS-CoV-2 and other emerging infectious diseases.

**DISCLOSURE**

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**REFERENCES**

1. Ghinai I, McPherson TD, Hunter JC, et al. First known person-to-person transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the USA. Lancet 2020;395(10230):1137–44. https://doi.org/10.1016/S0140-6736(20)30607-3.
2. Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med 2020;382(13):1199–207. https://doi.org/10.1056/NEJMoa2001316.
3. Sohrabi C, Alsafi Z, O’Neill N, et al. World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19). Int J Surg 2020; 76:71–6. https://doi.org/10.1016/j.ijsu.2020.02.034.

4. Vaccines WHO. Background paper on COVID-19 disease and vaccines 2020. Available at: WHO/2019-nCoV/vaccines/SAGE_background/2020.1. 12/22/2020.

5. Severe Acute Respiratory Syndrome (SARS). 2021. Available at: https://www.cdc.gov/sars/index.html. Accessed June 15, 2021.

6. Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003. 2021. Available at: https://www.who.int/publications/m/item/summary-of-probable-sars-cases-with-onset-of-illness-from-1-november-2002-to-31-july-2003. Accessed June 15, 2021.

7. WHO Coronavirus (COVID-19) Dashboard. 2021. Available at: https://covid19-who.int/?adgroupsurvey={adgroupsurvey}&gclid=CjwKCAjwqcKFBhAhEiwAfEr7zcePRhsL6jDD51Um33KtwAZ3TEKt11NLk0s1etQHwNiUDykgkqwvmOBoCfdUQAvD_BwE Accessed November 12, 2021

9. Information for pediatric healthcare providers. 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/pediatric-hcp.html. Accessed June 15, 2021.

10. Demographic trends of COVID-19 cases and deaths in the US reported to CDC. 2021. Available at: https://covid.cdc.gov/covid-data-tracker/?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2FCases-updates%2Fcases-in-us.html#demographics. Accessed June 15, 2021.

11. COVID-NET Laboratory-confirmed COVID-19 hospitalizations. 2021. Available at: https://covid.cdc.gov/covid-data-tracker/?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fcases-updates%2Fcases-in-us.html#covidnet-hospitalization-network. Accessed June 15, 2021.

12. Leidman E, Duca LM, Omura JD, et al. COVID-19 trends among persons aged 0-24 years - United States, March 1-December 12, 2020. MMWR Morb Mortal Wkly Rep 2021;70(3):88–94. https://doi.org/10.15585/mmwr.mm7003e1.

13. Kim L, Whitaker M, O’Halloran A, et al. Hospitalization rates and characteristics of children aged <18 years hospitalized with laboratory-confirmed COVID-19 - COVID-NET, 14 States, March 1-July 25, 2020. MMWR Morb Mortal Wkly Rep 2020;69(32):1081–8. https://doi.org/10.15585/mmwr.mm6932e3.

14. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting characteristics, comorbidities, and outcomes among 5730 patients hospitalized with COVID-19 in the New York City Area. JAMA 2020;323(20):2052–9. https://doi.org/10.1001/jama.2020.6775.

15. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72314 cases from the Chinese center for disease control and prevention. JAMA 2020; 323(13):1239–42. https://doi.org/10.1001/jama.2020.2648.

16. Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. JAMA 2020;323(18):1775–6. https://doi.org/10.1001/jama.2020.4683.

17. Ahmad FB, Cisewski JA, Minino A, et al. Provisional mortality data - United States, 2020. MMWR Morb Mortal Wkly Rep 2021;70(14):519–22. https://doi.org/10.15585/mmwr.mm7014e1.
18. Woodworth KR, Olsen EO, Neelam V, et al. Birth and infant outcomes following laboratory-confirmed SARS-CoV-2 infection in pregnancy - SET-NET, 16 jurisdictions, March 29-October 14, 2020. MMWR Morb Mortal Wkly Rep 2020;69(44):1635–40. https://doi.org/10.15585/mmwr.mm6944e2.

19. Chen H, Guo J, Wang C, et al. Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records. Lancet 2020;395(10226):809–15. https://doi.org/10.1016/S0140-6736(20)30360-3.

20. Godfred-Cato S, Bryant B, Leung J, et al. COVID-19-associated multisystem inflammatory syndrome in children - United States, March-July 2020. MMWR Morb Mortal Wkly Rep 2020;69(32):1074–80. https://doi.org/10.15585/mmwr.mm6932e2.

21. Assaker R, Colas AE, Julien-Marsollier F, et al. Presenting symptoms of COVID-19 in children: a meta-analysis of published studies. Br J Anaesth 2020;125(3):e330–2. https://doi.org/10.1016/j.bja.2020.05.026.

22. Byambasuren O, Bell K, et al. Estimating the extent of asymptomatic COVID-19 and its potential for community transmission: systematic review and meta-analysis. J Assoc Med Microbiol Infect Dis Can 2020. https://doi.org/10.3138/jammi-2020-0030.

23. Toba N, Gupta S, Ali AY, et al. COVID-19 under 19: a meta-analysis. Pediatr Pulmonol 2021;56(6):1332–41. https://doi.org/10.1002/ppul.25312.

24. Mair M, Singhavi H, Pai A, et al. A meta-analysis of 67 studies with presenting symptoms and laboratory tests of COVID-19 patients. Laryngoscope 2021;131(6):1254–65. https://doi.org/10.1002/lary.29207.

25. Liu Y, Gayle AA, Wilder-Smith A, et al. The reproductive number of COVID-19 is higher compared to SARS coronavirus. J Trav Med. 2020;27(2). https://doi.org/10.1093/jtm/taaa021.

26. Biggerstaff M, Cauchemez S, Reed C, et al. Estimates of the reproduction number for seasonal, pandemic, and zoonotic influenza: a systematic review of the literature. BMC Infect Dis 2014;14:480. https://doi.org/10.1186/1471-2334-14-480.

27. Koh WC, Naing L, Chaw L, et al. What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLoS One 2020;15(10):e0240205. https://doi.org/10.1371/journal.pone.0240205.

28. 2009 H1N1 early outbreak and disease characteristics. 2021. Available at: https://www.cdc.gov/h1n1flu/surveillanceqa.htm. Accessed June 15, 2021.

29. Measles. 2021. Available at: https://www.cdc.gov/vaccines/pubs/pinkbook/meas.html. Accessed June 15, 2021.

30. Marin MLA. Varicella (chickenpox). 2021. Available at: https://wwwnc.cdc.gov/travel/yellowbook/2020/travel-related-infectious-diseases/varicella-chickenpox. Accessed June 15, 2021.

31. Lauer SA, Grantz KH, Bi Q, et al. The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. Ann Intern Med 2020;172(9):577–82. https://doi.org/10.7326/M20-0504.

32. He X, Lau EHY, Wu P, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. Nat Med 2020;26(5):672–5. https://doi.org/10.1038/s41591-020-0869-5.

33. Kimball A, Hatfield KM, Arons M, et al. Asymptomatic and presymptomatic SARS-CoV-2 infections in residents of a long-term care skilled nursing facility...
- King County, Washington, March 2020. MMWR Morb Mortal Wkly Rep 2020; 69(13):377–81. https://doi.org/10.15585/mmwr.mm6913e1.

34. Wei WE, Li Z, Chiew CJ, et al. Presymptomatic transmission of SARS-CoV-2 - Singapore, January 23-March 16, 2020. MMWR Morb Mortal Wkly Rep 2020; 69(14):411–5. https://doi.org/10.15585/mmwr.mm6914e1.

35. Bai Y, Yao L, Wei T, et al. Presumed asymptomatic carrier transmission of COVID-19. JAMA 2020;323(14):1406–7. https://doi.org/10.1001/jama.2020.2565.

36. Rothe C, Schunk M, Sothmann P, et al. Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. N Engl J Med 2020;382(10):970–1. https://doi.org/10.1056/NEJMct2001468.

37. To KK, Tsang OT, Leung WS, et al. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. Lancet Infect Dis 2020;20(5): 565–74. https://doi.org/10.1016/S1473-3099(20)30196-1.

38. Wolfel R, Corman VM, Guggemos W, et al. Virological assessment of hospitalized patients with COVID-19. Nature 2020;581(7809):465–9. https://doi.org/10.1038/s41586-020-2196-x.

39. Zou L, Ruan F, Huang M, et al. SARS-CoV-2 viral load in upper respiratory specimens of infected patients. N Engl J Med 2020;382(12):1177–9. https://doi.org/10.1056/NEJMc2001737.

40. Air: guidelines for environmental infection control in health-care facilities (2003). 2021. Available at: https://www.cdc.gov/infectioncontrol/guidelines/environmental/background/air.html. Accessed June 15, 2021.

41. Klompas M, Baker MA, Rhee C. Airborne transmission of SARS-CoV-2: theoretical considerations and available evidence. JAMA 2020;324(5):441–2. https://doi.org/10.1001/jama.2020.12458.

42. Saiman L, Acker KP, Dumitruc D, et al. Infection prevention and control for labor and delivery, well baby nurseries, and neonatal intensive care units. Semin Perinatol 2020;44(7):151320. https://doi.org/10.1016/j.semperi.2020.151320.

43. Samet JM, Prather K, Benjamin G, et al. Airborne transmission of SARS-CoV-2: what we know. Clin Infect Dis 2021. https://doi.org/10.1093/cid/ciab039.

44. Tang JW, Bahnfleth WP, Bluyssen PM, et al. Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). J Hosp Infect 2021;110:89–96. https://doi.org/10.1016/j.jhin.2020.12.022.

45. Chia PY, Coleman KK, Tan YK, et al. Detection of air and surface contamination by SARS-CoV-2 in hospital rooms of infected patients. Nat Commun 2020;11(1):2800. https://doi.org/10.1038/s41467-020-16670-2.

46. Liu Y, Zhi N, Chen Y, et al. Aerodynamic characteristics and RNA concentration of SARS-CoV-2 aerosol in Wuhan Hospitals during COVID-19 Outbreak. bioRxiv 2020. https://doi.org/10.1101/2020.03.08.982637.

47. Noorimotlagh Z, Jaafarzadeh N, Martinez SS, et al. A systematic review of possible airborne transmission of the COVID-19 virus (SARS-CoV-2) in the indoor air environment. Environ Res 2021;193:110612. https://doi.org/10.1016/j.envres.2020.110612.

48. van Doremalen N, Bushmaker T, Morris DH, 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://doi.org/10.1056/NEJMcs2004973.

49. Tran K, Cimon K, Severn M, et al. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic
50. Clinical questions about COVID-19: questions and answers. 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/faq.html. Accessed June 15, 2021.

51. Infection prevention and control during health care when coronavirus disease (COVID-19) is suspected or confirmed: interim guidance. 2021. Available at: https://www.who.int/publications/i/item/WHO-2019-nCoV-IPC-2020.4. Accessed June 15, 2021.

52. Li Y, Qian H, Hang J, et al. Probable airborne transmission of SARS-CoV-2 in a poorly ventilated restaurant. Build Environ 2021;196:107788. https://doi.org/10.1016/j.buildenv.2021.107788.

53. Moriarty LF, Plucinski MM, Marston BJ, et al. Public health responses to COVID-19 outbreaks on cruise ships - worldwide, February-March 2020. MMWR Morb Mortal Wkly Rep 2020;69(12):347–52. https://doi.org/10.15585/mmwr.mm6912e3.

54. Hamner L, Dubbel P, Capron I, et al. High SARS-CoV-2 attack rate following exposure at a choir practice - Skagit County, Washington, March 2020. MMWR Morb Mortal Wkly Rep 2020;69(19):606–10. https://doi.org/10.15585/mmwr.mm6919e6.

55. James A, Eagle L, Phillips C, et al. High COVID-19 attack rate among attendees at events at a church - Arkansas, March 2020. MMWR Morb Mortal Wkly Rep 2020;69(20):632–5. https://doi.org/10.15585/mmwr.mm6920e2.

56. Mosites E, Parker EM, Clarke KEN, et al. Assessment of SARS-CoV-2 infection prevalence in homeless shelters - four U.S. cities, March 27-April 15, 2020. MMWR Morb Mortal Wkly Rep 2020;69(17):521–2. https://doi.org/10.15585/mmwr.mm6917e1.

57. Szablewski CM, Chang KT, Brown MM, et al. SARS-CoV-2 transmission and infection among attendees of an overnight camp - Georgia, June 2020. MMWR Morb Mortal Wkly Rep 2020;69(31):1023–5. https://doi.org/10.15585/mmwr.mm6931e1.

58. Emanuel EJ, Persad G, Upshur R, et al. Fair allocation of scarce medical resources in the time of Covid-19. N Engl J Med 2020;382(21):2049–55. https://doi.org/10.1056/NEJMsb2005114.

59. Calderwood MS, Deloney VM, Anderson DJ, et al. Policies and practices of SHEA Research Network hospitals during the COVID-19 pandemic. Infect Control Hosp Epidemiol 2020;41(10):1127–35. https://doi.org/10.1017/ice.2020.303.

60. Strategies for optimizing the supply of N95 respirators. 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/. Accessed August 15, 2021.

61. Wang Q, Bai Y, et al. Epidemiologic characteristics of COVID-19 in medical staff members of neurosurgery departments in Hubei province: a multicentre descriptive study. medRxiv 2020. https://doi.org/10.1101/2020.04.20.20064899.

62. Lai X, Wang M, Qin C, et al. Coronavirus disease 2019 (COVID-2019) infection among health care workers and implications for prevention measures in a tertiary hospital in Wuhan, China. JAMA Netw Open 2020;3(5):e209666. https://doi.org/10.1001/jamanetworkopen.2020.9666.

63. Kluytmans-van den Bergh MFQ, Buiting AGM, Pas SD, et al. Prevalence and clinical presentation of health care workers with symptoms of coronavirus disease 2019 in 2 dutch hospitals during an early phase of the pandemic. JAMA
64. Clifton GT, Pati R, Krammer F, et al. SARS-CoV-2 infection risk among active duty military members deployed to a field hospital - New York City, April 2020. MMWR Morb Mortal Wkly Rep 2021;70(9):308–11. https://doi.org/10.15585/mmwr.mm7009a3.

65. Fell A, Beaudoin A, D’Heilly P, et al. SARS-CoV-2 exposure and infection among health care personnel - Minnesota, March 6-July 11, 2020. MMWR Morb Mortal Wkly Rep 2020;69(43):1605–10. https://doi.org/10.15585/mmwr.mm6943a5.

66. Self WH, Tenforde MW, Stubblefield WB, et al. Seroprevalence of SARS-CoV-2 among frontline health care personnel in a multistate hospital network - 13 academic medical centers, April-June 2020. MMWR Morb Mortal Wkly Rep 2020;69(35):1221–6. https://doi.org/10.15585/mmwr.mm6935e2.

67. Shah VP, Breeher LE, Hainy CM, et al. Evaluation of healthcare personnel exposures to patients with severe acute respiratory coronavirus virus 2 (SARS-CoV-2) associated with personal protective equipment. Infect Control Hosp Epidemiol 2021;1:1–5. https://doi.org/10.1017/ice.2021.219.

68. Team CC-R. Characteristics of health care personnel with COVID-19 - United States, February 12-April 9, 2020. MMWR Morb Mortal Wkly Rep 2020;69(15):477–81. https://doi.org/10.15585/mmwr.mm6915e6.

69. Hughes MM, Groenewold MR, Lessem SE, et al. Update: characteristics of health care personnel with COVID-19 - United States, February 12-July 16, 2020. MMWR Morb Mortal Wkly Rep 2020;69(38):1364–8. https://doi.org/10.15585/mmwr.mm6938a3.

70. Heinzerling A, Stuckey MJ, Scheuer T, et al. Transmission of COVID-19 to health care personnel during exposures to a hospitalized patient - Solano County, California, February 2020. MMWR Morb Mortal Wkly Rep 2020;69(15):472–6. https://doi.org/10.15585/mmwr.mm6915e5.

71. Li L, Niu M, Zhu Y. Assessing the effectiveness of using various face coverings to mitigate the transport of airborne particles produced by coughing indoors. Aerosol Sci Technol 2020. https://doi.org/10.1080/02786826.2020.1846679.

72. Jefferson T, Foxlee R, Del Mar C, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. BMJ 2008;336(7635):77–80. https://doi.org/10.1136/bmj.39393.510347.BE.

73. Bartoszko JJ, Farooqi MAM, Alhazzani W, et al. 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(4):365–73. https://doi.org/10.1111/irv.12745.

74. Chu DK, Akl EA, Duda S, 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://doi.org/10.1016/S0140-6736(20)31142-9.

75. Tabatabaeizadeh SA. Airborne transmission of COVID-19 and the role of face mask to prevent it: a systematic review and meta-analysis. Eur J Med Res 2021;26(1):1. https://doi.org/10.1186/s40001-020-00475-6.

76. Wang X, Pan Z, Cheng Z. Association between 2019-nCoV transmission and N95 respirator use. J Hosp Infect 2020;105(1):104–5. https://doi.org/10.1016/j.jhin.2020.02.021.

77. Hendrix MJ, Walde C, Findley K, et al. Absence of apparent transmission of SARS-CoV-2 from two stylists after exposure at a hair salon with a universal
Infection Prevention During COVID-19

face covering policy - Springfield, Missouri, May 2020. MMWR Morb Mortal Wkly Rep 2020;69(28):930–2. https://doi.org/10.15585/mmwr.mm6928e2.

78. Doung-ngern P, Panjangampalthana A, et al. Associations between wearing masks, washing hands, and social distancing practices, and risk of COVID-19 infection in public: a cohort-based case-control study in Thailand. Lancet 2020.

79. WHO save lives: clean your hands in the context of COVID-19. 2021. Available at: https://cdn.who.int/media/docs/default-source/integrated-health-services-ihs/infection-prevention-and-control/who-hh-community-campaign-finalv3.pdf?sfvrsn=322df98f_2. Accessed June 15, 2021.

80. Interim infection prevention and control recommendations for healthcare personnel during the coronavirus disease 2019 (COVID-19) Pandemic. 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html. Accessed June 15, 2021.

81. Lynch JB, Davitkov P, Anderson DJ, et al. Infectious Diseases Society of America Guidelines on infection prevention for health care personnel caring for patients with suspected or known COVID-19. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa1063.

82. Bullard J, Dust K, Funk D, et al. Predicting infectious severe acute respiratory syndrome coronavirus 2 from diagnostic samples. Clin Infect Dis 2020;71(10):2663–6. https://doi.org/10.1093/cid/ciaa638.

83. van Kampen JJA, van de Vijver D, Fraaij PLA, et al. Duration and key determinants of infectious virus shedding in hospitalized patients with coronavirus disease-2019 (COVID-19). Nat Commun 2021;12(1):267. https://doi.org/10.1038/s41467-020-20568-4.

84. Cheng HY, Jian SW, Liu DP, et al. Contact tracing assessment of COVID-19 transmission dynamics in Taiwan and risk at different exposure periods before and after symptom onset. JAMA Intern Med 2020;180(9):1156–63. https://doi.org/10.1001/jamainternmed.2020.2020.

85. Infectivity of persons with repeated positive SARS-CoV-2 RT-PCR tests. 2020. Available at: https://www.cdc.go.kr/board/board.es?mid=a30402000000&bid=0030. Accessed May 20, 2020.

86. Discontinuation of transmission-based precautions and disposition of patients with SARS-CoV-2 infection in healthcare settings. 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/disposition-hospitalized-patients.html. Accessed June 15, 2021.

87. Interim guidance on ending isolation and precautions for adults with COVID-19. 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/hcp/duration-isolation.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2FSARS-CoV-2F2019-ncov%2Fcommunity%2Fstrategy-discontinue-isolation.html. Accessed June 15, 2021.

88. Kratzel A, Todt D, V’Kovski P, et al. Inactivation of severe acute respiratory syndrome coronavirus 2 by WHO-recommended hand rub formulations and alcohols. Emerg Infect Dis 2020;26(7):1592–5. https://doi.org/10.3201/eid2607.200915.

89. Rabenau HF, Kampf G, Cinatl J, et al. Efficacy of various disinfectants against SARS coronavirus. J Hosp Infect 2005;61(2):107–11. https://doi.org/10.1016/j.jhin.2004.12.023.

90. Kampf G, Todt D, Pfaender S, et al. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J Hosp Infect 2020;104(3):246–51. https://doi.org/10.1016/j.jhin.2020.01.022.
91. Ong SWX, Tan YK, Chia PY, et al. Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. JAMA 2020;323(16):1610–2. https://doi.org/10.1001/jama.2020.3227.

92. Kitano T, Piche-Renaud PP, Groves HE, et al. Visitor restriction policy on pediatric wards during novel coronavirus (COVID-19) outbreak: a survey study across North America. J Pediatr Infect Dis Soc 2020;9(6):766–8. https://doi.org/10.1093/jpids/piaa126.

93. Darcy Mahoney A, White RD, Velasquez A, et al. Impact of restrictions on parental presence in neonatal intensive care units related to coronavirus disease 2019. J Perinatol 2020;40(Suppl 1):36–46. https://doi.org/10.1038/s41372-020-0753-7.

94. Tworek JA, Khan F, Sekedat MD, et al. The utility of rapid nucleic acid amplification testing to triage symptomatic patients and to screen asymptomatic preprocedure patients for SARS-CoV-2. Open Forum Infect Dis 2021;8(1):ofaa607. https://doi.org/10.1093/ofid/ofaa607.

95. Lin EE, Blumberg TJ, Adler AC, et al. Incidence of COVID-19 in pediatric surgical patients among 3 US Children’s Hospitals. JAMA Surg 2020;155(8):775–7. https://doi.org/10.1001/jamasurg.2020.2588.

96. Otto WR, Geoghegan S, Posch LC, et al. The epidemiology of severe acute respiratory syndrome coronavirus 2 in a pediatric healthcare network in the United States. J Pediatr Infect Dis Soc 2020;9(5):523–9. https://doi.org/10.1093/jpids/piaa074.

97. Aslam A, Singh J, Robilotti E, et al. SARS CoV-2 surveillance and exposure in the perioperative setting with universal testing and personal protective equipment (PPE) policies. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa1607.

98. Bence CM, Jarzemkowski JA, Belter L, et al. COVID-19 pre-procedural testing strategy and early outcomes at a large tertiary care children's hospital. Pediatr Surg Int 2021;37(7):871–80. https://doi.org/10.1007/s00383-021-04878-2.

99. Haidar G, Ayres A, King WC, et al. Preprocedural SARS-CoV-2 testing to sustain medically needed health care delivery during the COVID-19 pandemic: a prospective observational study. Open Forum Infect Dis 2021;8(2):ofab022. https://doi.org/10.1093/ofid/ofab022.

100. Bowyer B, Thukral C, Patel S, et al. Outcomes of symptom screening and universal COVID-19 reverse transcriptase polymerase chain reaction testing before endoscopy in a community-based ambulatory surgery center. Gastrointest Endosc 2021;93(5):1060–1064 e1. https://doi.org/10.1016/j.gie.2020.10.001.

101. Larsen CG, Bub CD, Schaffler BC, et al. The impact of confirmed coronavirus disease 2019 (COVID-19) infection on ambulatory procedures and associated delays in care for asymptomatic patients. Surgery 2021;169(6):1340–5. https://doi.org/10.1016/j.surg.2021.01.005.

102. Tande AJ, Pollock BD, Shah ND, et al. Impact of the COVID-19 vaccine on asymptomatic infection among patients undergoing pre-procedural COVID-19 molecular screening. Clin Infect Dis 2021. https://doi.org/10.1093/cid/ciab229.

103. Patel A, Jernigan DB, 2019-nCoV CDC Response Team. Initial public health response and interim clinical guidance for the 2019 novel coronavirus outbreak - United States, December 31, 2019-February 4, 2020. MMWR Morb Mortal Wkly Rep 2020;69(5):140–6. https://doi.org/10.15585/mmwr.mm6905e1.

104. Dollard P, Griffin I, Berro A, et al. Risk assessment and management of COVID-19 among travelers arriving at designated U.S. airports, January 17-September 13, 2020. MMWR Morb Mortal Wkly Rep 2020;69(45):1681–5. https://doi.org/10.15585/mmwr.mm6945a4.
Infection Prevention During COVID-19

105. Haischer MH, Beilfuss R, Hart MR, et al. Who is wearing a mask? Gender-, age-, and location-related differences during the COVID-19 pandemic. PLoS One 2020;15(10):e0240785. https://doi.org/10.1371/journal.pone.0240785.

106. Guy GP Jr, Lee FC, Sunshine G, et al. Association of state-issued mask mandates and allowing on-premises restaurant dining with county-level COVID-19 case and death growth rates - United States, March 1-December 31, 2020. MMWR Morb Mortal Wkly Rep 2021;70(10):350–4. https://doi.org/10.15585/mmwr.mm7100e3.

107. Joo H, Miller GF, Sunshine G, et al. Decline in COVID-19 hospitalization growth rates associated with statewide mask mandates - 10 states, March-October 2020. MMWR Morb Mortal Wkly Rep 2021;70(6):212–6. https://doi.org/10.15585/mmwr.mm7006e2.

108. Kanu FA, Smith EE, Offutt-Powell T, et al. Declines in SARS-CoV-2 transmission, hospitalizations, and mortality after implementation of mitigation measures- Delaware, March-June 2020. MMWR Morb Mortal Wkly Rep 2020;69(45):1691–4. https://doi.org/10.15585/mmwr.mm6945e1.

109. Van Dyke ME, Rogers TM, Pevzner E, et al. Trends in county-level COVID-19 incidence in counties with and without a mask mandate - Kansas, June 1-August 23, 2020. MMWR Morb Mortal Wkly Rep 2020;69(47):1777–81. https://doi.org/10.15585/mmwr.mm6947e2.

110. Barrios LC, Riggs MA, Green RF, et al. Observed face mask use at six universities - United States, September-November 2020. MMWR Morb Mortal Wkly Rep 2021;70(6):208–11. https://doi.org/10.15585/mmwr.mm7006e1.

111. Hutchins HJ, Wolff B, Leeb R, et al. COVID-19 mitigation behaviors by age group - United States, April-June 2020. MMWR Morb Mortal Wkly Rep 2020;69(43):1584–90. https://doi.org/10.15585/mmwr.mm6943e4.

112. Green DN, Blumenkamp CK. Facemasking behaviors, preferences, and attitudes among emerging adults in the united states during the COVID-19 pandemic: an exploratory study. Cloth Text Res J 2021. https://doi.org/10.1177/0887302X211006775.

113. Gallaway MS, Rigler J, Robinson S, et al. Trends in COVID-19 incidence after implementation of mitigation measures - Arizona, January 22-August 7, 2020. MMWR Morb Mortal Wkly Rep 2020;69(40):1460–3. https://doi.org/10.15585/mmwr.mm6940e3.

114. Lyu W, Wehby GL. Comparison of estimated rates of coronavirus disease 2019 (COVID-19) in border counties in iowa without a stay-at-home order and border counties in Illinois With a Stay-at-Home Order. JAMA Netw Open 2020;3(5):e2011102. https://doi.org/10.1001/jamanetworkopen.2020.11102.

115. Fuller JA, Hakim A, Victory KR, et al. Mitigation policies and COVID-19-associated mortality - 37 European Countries, January 23-June 30, 2020. MMWR Morb Mortal Wkly Rep 2021;70(2):58–62. https://doi.org/10.15585/mmwr.mm7002e4.

116. Lash RR, Donovan CV, Fleischauer AT, et al. COVID-19 contact tracing in two counties - North Carolina, June-July 2020. MMWR Morb Mortal Wkly Rep 2020;69(38):1360–3. https://doi.org/10.15585/mmwr.mm6938e3.

117. Spencer KD, Chung CL, Stargel A, et al. COVID-19 case investigation and contact tracing efforts from health departments - United States, June 25-July 24, 2020. MMWR Morb Mortal Wkly Rep 2021;70(3):83–7. https://doi.org/10.15585/mmwr.mm7003a3.

118. Honein MA, Christie A, Rose DA, et al. Summary of guidance for public health strategies to address high levels of community transmission of SARS-CoV-2 and related deaths, December 2020. MMWR Morb Mortal Wkly Rep 2020; 69(49):1860–7. https://doi.org/10.15585/mmwr.mm6949e2.