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Infection Prevention during the Coronavirus Disease 2019 Pandemic



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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.

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

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(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

Manifestation	Pediatric, %^{21,23,24}	Adult, %^{22,24}
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

Data from Refs.^{21–24}

is 1.28, 1.46 for the 2009 H1N1 influenza epidemic, and 1.80 for the 1918 influenza pandemic.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%.²⁷ Variable attack rates were seen in nonhousehold, non-health care settings, ranging from 0% to 5.8% in larger studies (with >1000 contacts).²⁷ In comparison the estimated household secondary attack rates for 2009 H1N1 influenza epidemic ranged from 8% to 19%.²⁸ Secondary attack rates for selected pathogens transmitted via an airborne route include 90% for measles and 85% for varicella.^{29,30}

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.^{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.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.³² However, reports of asymptomatic and more commonly pre-symptomatic transmission quickly emerged,^{32–34} including evidence of person-to-person transmission during the pre-symptomatic phase and from fully asymptomatic individuals.^{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.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.^{37–39}

AIRBORNE VERSUS DROPLET

The classic distinction is between large ($>5\ \mu\text{m}$) 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 ($\leq 5\ \mu\text{m}$), and may remain suspended in the air for extended periods of time and travel greater distances.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.^{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.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.⁴⁴ Contributing to confusion surrounding this subject, terminology including airborne particles, aerosols, and droplets may be interpreted differently by infection prevention specialists and aerobiologists.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.^{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,^{45–47} raising the possibility of airborne transmission. In experimental models, SARS-CoV-2 remained stable in generated aerosols for 3 hours.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.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^{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.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.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.⁵⁴

Religious Services

Following exposure at various church events over a 6-day period, 38% of the 92 attendees developed COVID-19.⁵⁵

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.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%.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.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.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.⁶⁰

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.^{42,59} 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.⁵⁹

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.²⁷

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.^{62,68} Among health care setting exposures, contact with patients (63%) or colleagues with COVID-19 (31%) were the most common identified sources.⁶¹ 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%).^{65,69} 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.⁷⁰ 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.^{65,69} 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%).⁶⁵

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.⁶⁴ Taken as a whole, these data suggest that the risk of

Table 2
Severe acute respiratory syndrome coronavirus 2 attack rate in health care personnel

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 2021	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 from Refs.^{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.⁶¹

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.⁷⁹
- 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 precautions⁸⁰)
- 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.⁸¹

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.^{38,82,83} Exposure to an index case after day 5 of symptoms was not

associated with SARS-CoV-2 transmission in a large contact-tracing study.⁸⁴ 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.⁸⁵

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^{86,87}

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.^{88,89} 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.^{72,76}

Other coronaviruses have been found to persist on environmental surfaces for up to 9 days.⁹⁰ In experimental models, SARS-CoV-2 remained viable on hard surfaces for up to 72 hours after being applied,⁴⁸ and SARS-CoV-2 has been recovered after sampling environmental surfaces in COVID-19 patient rooms.⁴⁵ Experimental evidence has demonstrated that SARS-CoV-2 is inactivated with routine cleaning and disinfection measures, including quaternary ammonium-containing products.⁸⁹ 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.⁹¹

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.⁹⁶ In addition, percent positivity was lower in asymptomatic, vaccinated individuals undergoing pre-procedural testing compared with unvaccinated individuals.¹⁰²

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-19.⁹⁹ 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.¹⁰¹ 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%.¹⁰⁰

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.⁸⁰

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.^{59,92} For pediatric patients, 67% to 85% of health care facilities allowed 1 visitor per pediatric patient, and the remainder allowed 2.^{59,92} 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.⁹²

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.⁹³

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.¹⁰³ 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-2.¹⁰⁴

Local masking mandates were associated with an increase in masking compliance in those areas,¹⁰⁵ and decreased SARS-CoV-2 transmission rates, associated

Table 3 Pre-procedural testing					
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.^{106–109} Masking compliance varies based on age, sex, geographic setting, location of activity, and political affiliation.^{105,110–112}

Stay-at-home orders and other public health mitigation strategies are also effective at decreasing local SARS-CoV-2 transmission rates,^{108,113,114} with evidence of decreased mortality rates in areas with more stringent mitigation policies.¹¹⁵

Although efficient and early contact tracing can be an effective component in controlling SARS-CoV-2 outbreaks,⁸⁴ challenges in identifying and notifying contacts in a timely manner, particularly after increasing caseloads,^{116,117} 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 coverage¹¹⁸

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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