



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

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Precautions, Utilization of Personal Protective Equipment, and Conservation Strategies During the COVID-19 Pandemic



Priya Sampathkumar, MD; Elena Beam, MD; Laura E. Breeher, MD, MPH;
and John C. O'Horo, MD, MPH

The supply of personal protective equipment (PPE) during the coronavirus disease 2019 (COVID-19) pandemic has been severely compromised by high consumption and an unprecedented disruption in supply. In recent years, supply chains have been increasingly globalized and lean, approaches that are not resilient to a disaster of this magnitude. Before COVID-19, more than half of all face masks were manufactured in China.¹ As exports slowed during the pandemic, infection preventionists had to become stewards of PPE, reevaluating reuse strategies while keeping health care workers protected.

The initial Centers for Disease Control and Prevention guidance called for airborne, droplet, and contact precautions for all suspected cases.² This guidance immediately led to concerns that Mayo Clinic, like other facilities, did not have enough airborne infection isolation rooms, did not have adequate staff cleared and fit tested to wear air-purifying respirators, and would rapidly deplete existing respirator supplies without a clear mechanism for replenishing them.

We evaluated the evidence for routes of transmission of COVID-19. Overall, airborne transmission appeared less likely to be substantial on the basis of reports from the World Health Organization and experience with other coronaviruses. We therefore recommended a level we call “modified droplet precautions” (masks, eye protection, gowns, and gloves) for routine care with the

addition of a respirator (N95 or equivalent, eg, powered air-purifying respirator) only for aerosol-generating procedures (AGPs). Mayo Clinic made this change after the World Health Organization presented interim guidance supporting this approach.³ Additional respirator clearance and fit testing for staff continued, focused on those responsible for performing high- or medium-risk AGPs. At Mayo Clinic, patients with COVID-19 are not housed in airborne infection isolation rooms but room air exchanges per hour are closely tracked and used in determining how long a room needs to be closed between procedures. When respirators are required, we recommend all staff who enter the room continue to use their respirators until sufficient time has elapsed to ensure that any aerosolized infectious particles have been cleared.⁴

A major challenge with implementing modified droplet precautions was determining which procedures truly generated aerosols and thus required wearing of respirators. The Centers for Disease Control and Prevention recommendation is for respirators during nasopharyngeal swab collection.² This recommendation was not supported by existing evidence but led to a concern that various procedures with any potential to generate a cough may be AGPs, thus requiring respirator use.

We convened an AGP workgroup with subject matter experts from infection control, anesthesia, pulmonary and critical care medicine, respiratory therapy, and several

From the Division of Infectious Diseases (P.S., E.B., J.C.O.), Division of Preventive, Occupational and Aerospace Medicine (L.E.B.), and Division of Pulmonary and Critical Care Medicine (J.C.O.), Mayo Clinic, Rochester, MN.

TABLE. Three-Tiered System for Determining Requirements for PPE

Risk level	Definition	PPE requirement	Procedures
High	Clear risk of aerosol generation	Respirator, eye protection, gown, gloves	Intubation Bronchoscopy
Medium	Possible, but not substantial, risk of aerosol generation	For suspected COVID-19: respirator, eye protection, gown, gloves For other procedures: standard precautions for the procedure ^b	BiPAP/CPAP with a viral filter in place Nasogastric tube placement
Low	Little risk of aerosol generation	For suspected COVID-19: mask, eye protection, gown, gloves For other procedures: standard precautions for the procedure ^b	Nasopharyngeal swab collection Physiological coughing

^aBiPAP = bilevel positive airway pressure; COVID-19 = coronavirus disease 2019; CPAP = continuous positive airway pressure; PPE = personal protective equipment.

^bStandard precautions for procedures and patient care in which COVID-19 is not suspected and the risk of aerosol generation is not high are masks for the patient and health care worker or mask plus eye protection for the health care worker in any situation in which the patient cannot reliably be masked.

procedural services to evaluate commonly performed procedures for their potential to generate aerosols. Ultimately, we developed a 3-tiered system defining risk level and need for PPE, including respirators (Table). *High-risk procedures* were defined as those with a clear risk of aerosol generation. During the pandemic, staff performing such procedures for any patient would wear respirators. *Medium-risk procedures* were defined as those in which aerosol generation was possible but not likely substantial; thus, clinical suspicion for COVID-19 would guide whether respirators were required. *Low-risk procedures* were defined as those with minimal chance of aerosol exposure; thus, a respirator was not required. This system is updated as needed on the basis of discussions with stakeholders, but the framework has allowed us to classify procedures within a relatively simple algorithm on the basis of procedural risk and degree of suspicion for COVID-19.

As the COVID-19 pandemic continued, increased community spread occurred in the United States. In communities Mayo Clinic serves, we became concerned about the potential for asymptomatic viral shedding resulting in exposures to our health care workers. We began to require

universal masking of our patient-facing staff (surgical masks), then all staff, and finally patients and visitors, who could wear cloth masks. We provided guidance to reduce PPE consumption, such as reuse of masks, use of reusable full-face shields to protect masks from droplets contamination, and cleaning powered air-purifying respirator hoods.

Despite universal masking, employee exposures continued because of the inability of certain populations to mask reliably, such as small children and confused or agitated adults. Therefore, we added a requirement for universal use of eye protection by staff in these settings. With these interventions, employee exposures to COVID-19 decreased markedly.

We continue to explore options for reuse of masks, including reprocessing by cleaning with ultraviolet light disinfection and vaporized hydrogen peroxide. We have also identified sources of nontraditional PPE to augment existing supplies, such as full-face shields made by 3-dimensional printing for our health care workers and donated cloth masks for patients who do not have their own.

Coronavirus disease 2019 will continue to present challenges for infection prevention, employee safety, and supply chains.

Nonetheless, with rational use of PPE, creative sourcing, reuse, and extended use, we can meet this challenge for the duration of the pandemic.

ACKNOWLEDGMENTS

Editing, proofreading, and reference verification were provided by Scientific Publications, Mayo Clinic.


This supplement is sponsored by Mayo Clinic Foundation for Medical Education and Research and is authored by experts from multiple Departments and Divisions at Mayo Clinic.

Potential Competing Interests: Dr O'Horo serves as a consultant for Elsevier (outside the submitted work). The other authors report no competing interests.

Correspondence: Address to Priya Sampathkumar, MD, Division of Infectious Diseases, Mayo Clinic, 200 First St

SW, Rochester, MN 55905 (Sampathkumar.Priya@mayo.edu; Twitter: @PSampathkumarMD).

ORCID

Elena Beam:  <https://orcid.org/0000-0002-5807-2299>;
Laura E. Breeher:  <https://orcid.org/0000-0002-6327-5162>; John C. O'Horo:  <https://orcid.org/0000-0002-0880-4498>

REFERENCES

1. Ranney ML, Griffeth V, Jha AK. Critical supply shortages—the need for ventilators and personal protective equipment during the Covid-19 pandemic. *N Engl J Med.* 2020;382(18):e41.
2. Infection control guidance for healthcare professionals about coronavirus (COVID-19). Centers for Disease Control and Prevention website. <https://www.cdc.gov/coronavirus/2019-nCoV/hcp/infection-control.html>. Accessed May 14, 2020.
3. Rational use of personal protective equipment for coronavirus disease 2019 (COVID-19): interim guidance, 27 February 2020. World Health Organization website. <https://apps.who.int/iris/handle/10665/331215>. Accessed May 14, 2020.
4. Appendix B. Air: Guidelines for Environmental Infection Control in Health-Care Facilities (2003). Centers for Disease Control and Prevention website. <https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html>. Accessed May 14, 2020.