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Original Article

Health and Safety Regulations for COVID-19: A Policy Analysis

Lisa M. Brosseau[1,*], Rachael M. Jones[2,3], Kate Gardner[3], Spencer C. Williams[3], Kimberly P. Henry[4] and Denali Sanders[5]

[1]Center for Infectious Disease Research and Policy, University of Minnesota, 420 Delaware St SE, Minneapolis, MN 55455, USA;
[2]Department of Environmental Health Sciences, Fielding School of Public Health, University of California, 50 Charles E Young Dr S, Los Angeles, CA 90095, USA;
[3]Department of Family and Preventive Medicine, Spencer Fox Eccles School of Medicine, University of Utah, 375 Chipeta Way Suite A, Salt Lake City, UT 84108, USA;
[4]SAIF, 400 High St SE, Salem, OR 97312, USA;
[5]Department of Environmental Health and Radiological Health Sciences, Colorado State University, 122A Environmental Health Building, Fort Collins, CO 80523, USA

[*]Author to whom correspondence should be addressed. Tel: (612) 626-6770; e-mail: brosseau@umn.edu

Abstract

The COVID-19 pandemic spurred some regulators in the USA to require occupational health and safety programs to prevent COVID-19 transmission in workplaces. The objective of this study was to describe such state and federal regulations enacted between January 2020 and January 2022. Regulations, including emergency temporary standards (ETS) and permanent standards, were identified through a search of Nexis Uni and Bloomberg Law and review of US OSHA websites and the *Federal Register*. Full texts were reviewed for regulatory scope, hazard and exposure definitions, determination of exposure or risk levels, and control strategies. Four state (California, Michigan, Virginia, and Oregon) and two federal regulations were identified. All regulations described respiratory aerosols as the primary source of SARS-CoV-2 and recognized person-to-person transmission by droplet, airborne, and contact routes. Only the US OSHA ETS for healthcare explicitly stated that inhalation of respiratory particles was the most likely method of COVID-19 transmission. The Virginia, Michigan, and Oregon regulations described different categories of risk defined by exposure frequency and duration or specific workplace activities. California described exposure as places and times when employees come into contact or congregate with other people. The US OSHA ETS for healthcare described exposure as involving close contact with suspected or confirmed COVID-19 patients. While all of the state regulations required strategies from across the hierarchy, only the Virginia regulations specifically incorporated the hierarchy of controls. Only the California and Virginia regulations explicitly linked control strategies to the transmission route, while Virginia demarcated control strategies by risk level. Oregon linked risk level to occupancy levels and physical distancing requirements and referred to the use of a layered approach for transmission control. The US OSHA ETS for healthcare defined droplet and airborne precautions but made no mention of the hierarchy of controls or risk levels. Respirators were discussed in most of the regulations. The first Michigan regulation explicitly required respirators appropriate to exposure risk. The California regulations noted that respirators protect the wearer while face coverings protect people around the wearer. These regulations offer insights for a permanent US OSHA infectious disease regulation, such as the need to consider a range of transmission modes including near- and far-range aerosol inhalation, endemic and novel pathogens, workplaces beyond healthcare settings, factors that contribute to exposure and risk, the hierarchy of controls, the role of vaccination, and the importance of written exposure assessment and infection prevention plans.

Keywords: COVID-19; health and safety program; hierarchy of controls; infectious disease; policy; regulation; risk level; standard

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What's Important About this Paper?

During the COVID-19 pandemic, the US federal government and four states promulgated pandemic-related occupational health regulations. This study assessed the content of these regulations relative to scope, hazard and exposure definitions, determination of exposure or risk levels, and control strategies. All of these regulations had limitations, but the analysis identified the need for innovative risk assessment methods and characteristics for a future, more comprehensive regulation to protect workers from infectious diseases.

Introduction

The need to prevent transmission of respiratory infectious diseases in workplaces has been highlighted by the coronavirus infectious disease 2019 (COVID-19) pandemic, but this hazard has rarely been considered in US workplace health and safety regulations. For example, the US Occupational Safety and Health Administration (OSHA) issued a Proposed Rule on Occupational Exposure to Tuberculosis in 1997 that would have provided protection for workers exposed to *Mycobacterium tuberculosis* in correctional facilities, homeless shelters, and a variety of healthcare settings, among other workplaces (OSHA, 1997); the proposal was withdrawn in 2003 (OSHA, 2003).

In 2010, OSHA initiated public information gathering as part of the process to establish an Infectious Diseases standard, which would address exposures to all infectious diseases through all transmission routes in healthcare facilities, broadly defined (OSHA, 2010). OSHA's Infectious Disease Regulatory Framework required employers to develop a Worker Infection Control Plan that identifies exposures and details written standard operating procedures for all affected jobs (OSHA, 2014). This rulemaking was placed on OSHA's long-term action list in 2017. Recently, OSHA indicated an intent to publish a notice of proposed rulemaking in May 2023 (OSHA, 2022a).

The 1991 OSHA Bloodborne Pathogens (BBP) Standard (29 Code of Federal Regulations [CFR] 1910.1030) is the only US OSHA regulation that directly addresses workplace exposures to infectious diseases. The BBP Standard takes a precautionary approach requiring a presumption that anyone (workers, members of the public, patients, etc.) exposed to bloodborne infectious materials may become infected and that all materials with human blood, blood components, and products made from human blood may be infectious. Contact with these materials requires at least universal precautions, which may include hand hygiene, personal protective equipment, safe injection practices, and safe management of contaminated equipment. Additional engineering precautions, such as eliminating needles or requiring the use of safety-engineered sharps devices, are required for higher-risk tasks and exposures.

Twenty-two states currently manage an approved OSHA regulatory program covering private and public sector (state and local government) employees; an additional six states have a state-run OSHA program that covers only public employees (OSHA, 2022b). Where there is not an approved state OSHA program, federal OSHA is responsible for regulating the workplace health and safety of private employers. States with their own OSHA programs must promulgate regulations at least as effective as those of US OSHA but may also have additional or more restrictive regulations. The four states with COVID-19 OSHA regulations described in this paper (Michigan, Virginia, California, and Oregon) are among the 22 that manage their own OSHA programs for private and public sector employers.

At the state level, the 2009 California OSHA Aerosol Transmissible Diseases (ATD) Standard requires employers with workers at elevated risk (i.e. in healthcare and similar settings) of contracting a disease caused by an aerosol transmissible pathogen to have a written exposure control plan (California Code of Regulations [CCR] Title 8, Section 5188) (California Occupational Safety and Health Administration, 2009). The ATD Standard applies to all diseases and pathogens requiring droplet or airborne precautions as per public health guidelines (Siegel *et al.*, 2007), and to novel diseases and pathogens when there is no evidence to rule out with reasonable certainty the possibility that transmission involves 'dissemination of airborne droplet nuclei, small particle aerosols, or dust particles containing the infectious agent.' A written Exposure Control Plan is required that identifies, among other requirements, job classifications of employees with exposures, high-hazard procedures, assignments, and tasks requiring employees to wear respiratory protection, and procedures to identify and isolate cases and suspected cases in airborne infection isolation rooms (AIIRs) and other areas.

Although the Centers for Disease Control and Prevention (CDC) and state departments of public health do not have regulatory authority over workplace health and safety, their guidelines and input are important to and often inform OSHA regulations addressing infectious diseases. The National Institute

for Occupational Safety and Health (NIOSH), a CDC institute, played a key role in the development of the OSHA Bloodborne Pathogens standard. The California Department of Public Health (CDPH) was an important partner in the development of the ATD standard, which references CDPH and CDC guidelines. In healthcare organizations, workplace health and safety requirements may derive from federal or state OSHA regulations, licensure requirements typically overseen by state departments of health, accreditation managed by The Joint Commission (an independent organization), and requirements from the Centers for Medicare and Medicaid Services (a federal agency). The CMS and CDC collaborate on infection control guidelines for healthcare organizations and jointly oversee national reporting on healthcare-related infections.

The infectious disease regulations described above are programmatic in nature, requiring employers to develop a written plan that identifies jobs and tasks where exposures may occur and describe the policies and procedures that will be used to prevent these exposures. With the COVID-19 pandemic, workplace health and safety regulations were promulgated by several entities in the USA. The objective of this study was to identify, review, and compare workplace health and safety regulations promulgated by state and federal agencies in the USA in response to the COVID-19 pandemic.

Methods

State regulations were identified by searching Nexis Uni and Bloomberg Law databases. Two search strings were used: 'occupational AND exposure AND COVID' and 'occupational exposure AND COVID' in conjunction with a limit to search statutory codes published before 31 December 2021. The statutory code limit centered the search on administrative codes and regulations and reduced the number of executive orders returned. The databases identified regulations current as of December 2021; earlier and later versions were located by a search of the appropriate state OSHA program website. Federal regulations were identified through a search of the US OSHA website and *Federal Register*. Full texts through January 2022 were obtained.

Regulations were included if they described comprehensive workplace health and safety programs; executive orders or directives limited to masking and physical distancing in workplaces or public spaces were excluded. Data were extracted from each regulation using the matrix method (Goldman and Schmalz, 2004). Three broad areas were identified for data extraction: (i) definitions of key terms related to the regulatory scope and hazard recognition; (ii) approaches used to identify levels of exposure and risk, and (iii) required intervention strategies. These areas were selected for data extraction because they were common to the regulations and consistent with the industrial hygiene paradigm to anticipate, recognize, assess, and control workplace hazards. Within each of these broader areas, subcategories were developed for data extraction.

Results

Nexis Uni and Bloomberg Law returned 234 and 372 results, respectively; restricting the time period and duplications eliminated 139 and 286 results from the two databases. Application of the inclusion and exclusion criteria identified regulations from four states: California, Michigan, Oregon, and Virginia. These four states all have state-based OSHA programs, which can set their own regulations and must meet, but may exceed, federal OSHA requirements. An additional California Emergency Temporary Standard (ETS) promulgated in January 2022 was found by searching the California OSHA website. Two federal regulations were identified. The timeline of all identified regulations is shown in Table 1.

Regulations

Virginia was the first to promulgate an ETS (VA-ETS) in July 2020: *Standard for Infectious Disease Prevention of the SARS-COV-2 Virus that Causes COVID-19* (16VAC24-220-10) (Virginia Safety and Health Codes Board, 2020), which was adopted as a Permanent Standard (VA-PS) in January 2021 (Virginia Safety and Health Codes Board, 2021a) and amended (VA-AMN) in August 2021 (Virginia Safety and Health Codes Board, 2021b) (Table 1). (This standard was repealed on 23 March 2022).

Michigan promulgated an ETS (MI-ETS1) in October 2020: *Emergency Rule Coronavirus Disease 2019 (COVID-19)* (Michigan Occupational Safety and Health Administration, 2020). This was followed by a second ETS (MI-ETS2) in May 2021 (Michigan Occupational Safety and Health Administration, 2021a) that was replaced in June 2021 by a third ETS (MI-ETS3) (Michigan Occupational Safety and Health Administration, 2021b). MI-ETS3 applied only to healthcare workplaces, incorporated the federal OSHA ETS, and expired in December 2021 (Table 1).

California promulgated an ETS (CA-ETS1) in November 2020: *COVID-19 Prevention* (Title 8 Section 3205) (California Occupational Safety and Health Administration, 2020). Upon expiry, two further ETSs were promulgated (CA-ETS2, CA-ETS3)

Table 1. State and federal regulations timeline, scope, and definitions of hazard and exposure

Title	Date	Scope	Hazard	Exposure(s)
Virginia (VA)				
VA-ETS	7/2020	Employees and places of employment under jurisdiction of VA OSH.	SARS-CoV-2	Airborne transmission, contaminated surfaces**
VA-PS	1/2021	Employees and places of employment under jurisdiction of VA OSH.	SARS-CoV-2	Respiratory droplets, airborne transmission, contact
VA-AMN	7/2021	Employees and places of employment under jurisdiction of VA OSH.	SARS-CoV-2	Respiratory droplets, aerosols, contact
Michigan (MI)				
MI ETS1	10/2020	All employees covered by MI OSHA	People known to be or suspected of being infected with SARS-CoV-2, contaminated surfaces	Respiratory aerosols, contaminated surfaces
MI ETS2	5/2021	All employees covered by MI OSHA	SARS-CoV-2, people with COVID-19	Respiratory aerosols
Oregon (OR)				
OR-ETS	11/2020	Employees and places of employment under jurisdiction of OR OSHA.	COVID-19, individual who has tested positive for COVID-19.*	Droplets, contact, airborne modes
OR-PS	5/2021	Employees and places of employment under jurisdiction of OR OSHA who are exposed to 1 or more individuals outside of their household.	SARS-CoV-2, individual who has tested positive for COVID-19*	Droplets, contact, airborne modes
OR-AMN	6/2021, 8/2021, 9/2021	Employees and places of employment under jurisdiction of OR OSHA who are exposed to 1 or more individuals outside of their household.	SARS-CoV-2, individual who has tested positive for COVID-19*	Droplets, contact, airborne modes
California (CA)				
CA-ETS1 CA-ETS2 CA-ETS3	11/2020 6/2021 1/2022	All workplaces and workers except those working from home, having no contact, or covered by the Aerosol Transmissible Disease standard	COVID-19 Case	Airborne droplet, small particle aerosols, airborne droplet nuclei, contaminated surfaces or objects. Within 6 feet of a COVID-19 case for 15 min cumulative over 24 h period.
Federal (US)				
US-ETS-HC	6/2021	All settings where any employee provides healthcare services or healthcare support services (with some (exceptions)	SARS-CoV-2, COVID-19	Most common: person-to-person contact within 6 ft by inhalation of respiratory particles (droplets and aerosols). Less common: airborne transmission of smaller droplets and particles over longer distances and contact.
US-ETS-VT	11/2021	All employers with ≥100 employees, except those covered by US-ETS-HC, federal contractors and subcontractors, and people who work alone, from home, or outdoors.	SARS-CoV-2, COVID-19	Same as ETS HC, which is incorporated into this ETS.

*Referred to as COVID-19 throughout, notification section discusses in terms of an individual who has tested positive for COVID-19.
**Droplet is listed in the definitions of various types of PPE, 'respiratory emissions.' No explicit infectious materials or modes of transmission listed.

(California Occupational Safety and Health Administration, 2021, 2022) (Table 1). (CA-ETS3 expired in May 2022; a fourth ETS was promulgated in May 2022 and remains in effect until 31 December 2022, but is not reviewed or discussed in this paper.)

Oregon promulgated an ETS (OR-ETS) in November 2020: *Rule Addressing COVID-19 Workplace Risks* (OAR 437-001-0744) (Oregon Occupational Safety and Health Division, 2020), which became a Permanent Standard (OR-PS) in May 2021 (Oregon Occupational Safety and Health Division, 2021) and was amended (OR-AMN) in June, August, and September 2021 (Table 1). The permanent standard was amended in September 2022 and remains in effect but will be repealed when the pandemic ends.

At the federal level, US OSHA promulgated the *COVID-19 Healthcare Emergency Temporary Standard* (US-ETS-HC, 29 CFR 1910 Subpart U) in June 2021, which expired in December 2021 (OSHA, 2021a). In November 2021, US OSHA promulgated the *Vaccination and Testing Emergency Temporary Standard* (US-ETS-VT, 29 CFR 1910 Subpart U) for non-healthcare workplaces (OSHA, 2021b), which was stayed by the US Supreme Court and withdrawn by OSHA in January 2022 (Table 1).

Scope and hazard definitions

The scope for all state regulations included all workers within the jurisdiction of the state's OSHA program (Table 1); California and Oregon excluded those who work from home or have no contact with other people. Oregon required the provision of a COVID-19 hazards poster to remote workers. California excluded workers and workplaces already covered by the ATD Standard. At the federal level, the US-ETS-HC included settings that provide healthcare services and support, while the US-ETS-VT included workers in large employers outside the scope of the US-ETS-HC.

Most of the regulations referred to the virus, SARS-CoV-2, as the hazard, although many also identified the disease COVID-19 or an individual with COVID-19 as the hazard (Table 1). The two federal regulations explicitly state that COVID-19 and SARS-CoV-2 are used interchangeably.

While the terminology differs, all of the regulations describe respiratory aerosols as the primary source of SARS-CoV-2 and person-to-person transmission by the traditional routes of droplet, airborne, and contact (Table 1). The CA-ETS, MI-ETS, VA-PS, and VA-AMN and both US-ETS explicitly mention aerosols. Only the federal regulations specifically reference the CDC descriptions and guidelines about how COVID-19 is transmitted. In the MI-ETS-2, contaminated surfaces were dropped as a source of exposure.

Exposure and risk assessment

Risk levels were not discussed or identified in either of the US-ETS. Three states (Michigan, Oregon, and Virginia) required the employer to assess exposures or risks (Table 2). In the MI-ETS-1, the employer was required to evaluate tasks and procedures associated with employee exposure to SARS-CoV-2 and assign the work activity to one of four risk levels (lower, medium, high, and very high). The MI-ETS-2 omitted these risk levels and dropped all discussions of risk assessment. The VA-ETS and VA-PS described the same four levels of risk, but the VA-AMN eliminated these levels and divided risk by type of workplace in three categories (e.g. all workplaces, healthcare or healthcare support services, and higher-risk workplaces)

In the MI-ETS1, risk categories were based on the frequency of contact with the general public or suspected or confirmed COVID-19 cases. The 'lower' category included workplaces with no contact with suspected or confirmed infected people or infrequent close contact with the general public. The 'medium' category included workplaces with frequent or close contact with people who may be infected but are not suspected or confirmed patients, including the general public. The 'high' category included workplaces with a high potential for exposure to known or suspected sources of SARS-CoV-2, while 'very high' was reserved for workplaces with high potential for exposure to known or suspected COVID-19 cases or SARS-CoV-2 during specific medical, healthcare, postmortem, or lab procedures.

The Oregon standards identified specific workplaces posing 'exceptional' risk for COVID-19 transmission; the remainder were considered general workplaces. Exceptional risk was defined as 'Direct patient care, aerosol-generating healthcare or postmortem procedures, emergency responder, client service in long-term care or assisted living, handling human tissues, specimens or lab cultures from COVID suspect or patients.' For other workplaces, Oregon OSHA offered an exposure risk assessment form as a guide for employers, which included questions about the nature of work and the use of required control strategies but did not assess the degree or level of exposure or risk.

The VA-ETS and VA-PS, like the Michigan regulations, defined risk categories in the context of contact and frequency, but also identified co-worker contacts as a feature of exposure and considered the role of control strategies. Lower levels of risk were identified by first ruling out higher risk levels. Specific jobs and workplaces were described for the higher-risk categories. Risk categories are:

- Lower: Not very high, high, or medium. No close contact with known or suspected COVID-19 cases. Minimal contact with co-workers or public,

Table 2. Exposure and risk assessment requirements, basis of determination and categories

Standard	Required of employer	Basis of determination	Risk categories
VA-ETS and VA-PS	Yes	Tasks, work environment, presence of virus or someone with COVID-19, number of people, size of work area, duration and frequency of contact within 6 ft, type of exposure (airborne or contact), shared spaces or transportation. The greater the frequency or length of time of the exposure, the greater the probability is for potential infection to occur.	Lower, medium, high, very high
VA-AMN	Yes	All workplaces: Hazards and job tasks that can expose employees to SARS-CoV-2 virus or COVID-19 disease. Tasks that are similar in nature and employees exposed to the same hazard may be grouped for classification purposes. (See text for healthcare and higher-risk workplaces.)	All workplaces; healthcare or healthcare support services; higher risk workplaces
MI-ETS1	Yes	Likelihood and frequency of contact with people known or suspected to be infected with COVID-19 or with the public and co-workers.	Lower, medium, high, very high
MI ETS2	No	Not discussed	Not discussed
CA-ETS1, CA-ETS2, and CA-ETS3	No	Places and times when employees come into contact or congregate. Includes anyone entering, leaving, traveling through, or located at the workplace.	Not discussed
OR-ETS, OR-PS, and OR-AMN	Yes*	Per definition to determine if exceptional risk,** otherwise general workplace	Workplaces at exceptional risk**; all other workplaces
US-ETS-HC	No	The employer must conduct a workplace-specific hazard assessment to identify potential workplace hazards related to COVID–19. Exposure defined as close contact (within 6 feet for 15 min or more) with suspected or confirmed COVID-19 persons or when an aerosol-generating procedure is conducted on a person with suspected or confirmed COVID-19***	Not discussed
US-ETS-VT	No	Not discussed	

*Without regard to the use of personal protective equipment, masks, face coverings, or face shields.
**Direct patient care, environment decontamination services in a healthcare setting, aerosol-generating healthcare or postmortem procedures, direct client service in residential care or assisted living facilities, emergency first responder activities, personal care activities that involve very close contact, or handling human remains, tissue specimens or laboratory cultures from suspect or confirmed COVID-19 patients.
***Implied by the PPE requirements, not directly stated as a definition for exposure.

or are able to achieve minimal contact with engineering, administrative, and work practices.

- Medium: Not classified as high or very high. More than minimal close contact with co-workers or public who may be infected but are not known or suspected to have COVID-19. (Includes specific jobs and workplaces.)
- High: High potential for close contact with known or suspected sources of SARS-CoV-2 or with persons known or suspected to be infected with SARS-CoV-2, but not otherwise classified as very high exposure risks. (Includes specific jobs and tasks.)
- Very high: High potential for exposure to known or suspected sources of SARS-CoV-2 virus or persons known or suspected to be infected with SARS-CoV-2, including medical, postmortem, or lab procedures.

The risk categories were revised in the VA-AMN, which described the risk as: 'Where employees are not fully vaccinated, working close together, or have prolonged close contact to coworkers or potential frequent contact with public not fully vaccinated, or work in enclosed spaces with inadequate ventilation where coworkers or public are present, or may be exposed to infectious respiratory droplets or aerosols in air or from contact with contaminated objects/surfaces, or share space in breakrooms, locker rooms, entrances/exits, or shared transportation, or communal housing/living quarters.'

Table 3. Control Strategies Included in the Standard

Y = yes N = no S = somewhat	MI ETS1	MI ETS2	VA ETS	VA PS	VA AMN	CA ETS1	CA ETS2	CA ETS3	OR ETS	OR PS	OR AMN	US ETS HC	US ETS VT
Are control strategies associated with modes of transmission?	N	N	S	S	S	S (3)	S (3)	S (3)	S (17)	S (17)	S (17)	Y	N
Are multiple controls recommended?	N	N	Y	Y	Y	S (3)	S (3)	S (3)	Y	Y	Y	N	N
Are control strategies based on risk level?	N (9)	N	Y	Y	Y	N	N	N	S (12)	S (12)	S	N	N
Is there a hierarchy of controls?	N	N	Y	Y	Y	N	N	N	N	N (20)	N	N	N
Does the standard mention source controls?	N	N	N	Y	N	N	N	N	Y (11)	Y (11)	Y (11)	N	N
Does the regulation address these controls?													
Screening workers, clients, patients, etc.	Y	Y	Y	Y	Y	Y	Y	Y	Y (13)	Y (13)	Y (18)	Y	N
Vaccination	N	N	N	N	Y	N	Y (5)	Y (6)	N	N	N	Y	Y
Testing	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Working remotely	Y	Y	Y	Y	Y	Y (1)	Y (1)	Y (1)	Y	Y	Y	N	N
Physical distancing	Y	Y	N	N	N	Y (1)	Y (1)	Y (1)	Y	Y	N	Y	N
Limit occupancy numbers	Y	N	Y	Y	Y	N	N	N	N	N	N	N	N
Cleaning and disinfection of surfaces and objects	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	N
Hand washing	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Engineering controls		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Ventilation	Y (10)	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Ventilation Filtration	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Increase outside air	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N
Portable HEPA filtration units or other air cleaning devices	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
Administrative controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Employee training	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Case Investigation/Contact Tracing	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N
Policy or procedure for reporting exposure	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y

Table 3. Continued

Y = yes N = no S = somewhat	MI ETS1	MI ETS2	VA ETS	VA PS	VA AMN	CA ETS1	CA ETS2	CA ETS3	OR ETS	OR PS	OR AMN	US ETS HC	US ETS VT
Recordkeeping	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Exclusion of cases/Medical removal	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Access to testing at no cost to employee	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Return to work criteria	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Access to medical records/ data	N	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	N
Privacy of medical records	N	N	N	N	N	Y	Y	Y	N	N	N	Y	Y
Personal protective equipment	Y (7,8)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Use of face coverings	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Use of face shields	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Gloves	Y (8)	N	Y	Y	Y	Y	Y	Y	Y (14)	Y (14)	Y (14)	Y	N
Goggles	Y (8)	N	Y	Y	Y	Y	Y	Y	Y (15)	Y (15)	Y (18)	Y	N
Use of facemasks (surgical masks)	N	N	N	N	Y	N	Y (2)	Y (2)	Y (19)	Y (19)	N	Y	Y
Use of respirators	Y	N	Y	Y	Y	Y (4)	Y (4)	Y (4)	Y (16)	Y (16)	Y (16)	Y	Y
Voluntary use of respirators	N	N	Y	Y	Y	N	Y (2)	Y (2,6)	Y	Y	Y	Y	Y

(1)Methods of physical distancing include telework or other remote work arrangements; reducing the number of persons in an area at one time, including visitors; visual cues such as signs and floor markings to indicate where employees and others should be located or their direction and path of travel; staggered arrival, departure, work, and break times; and adjusted work processes or procedures, such as reducing production speed, to allow greater distance between employees.
(2)Considered a 'face covering'.
(3)Training must include the fact that COVID-19 is an infectious disease that can be spread through the air when an infectious person talks or vocalizes, sneezes, coughs, or exhales; that COVID-19 may be transmitted when a person touches a contaminated object and then touches their eyes, nose, or mouth, although that is less common; and that an infectious person may have no symptoms. Training must include the fact that particles containing the virus can travel more than six feet, especially indoors, so physical distancing, face coverings, increased ventilation indoors, and respiratory protection decrease the spread of COVID-19 but are most effective when used in combination.
(4)N95s and more protective respirators protect the users from airborne disease while face coverings primarily protect people around the user.
(5)Must provide employees with information regarding COVID-19-related benefits to which the employee may be entitled under applicable federal, state, or local laws, including any benefits available under legally mandated sick and vaccination leave, if applicable, workers' compensation law, local governmental requirements, the employer's own leave policies, leave guaranteed by contract, and this section.
(6)Right of employees who are not fully vaccinated to request a respirator for voluntary use as stated in this section, without fear of retaliation and at no cost to employees.
(7)The employer shall provide employees with the types of personal protective equipment, including respirators, if necessary, for protection from SARS-CoV-2 appropriate to the exposure risk associated with the job. The employer must follow current CDC and OSHA guidance for personal protective equipment.

Table 3. Continued

(8)In establishments that provide medical treatment or housing to known or suspected cases of COVID-19, the employer shall ensure that employees in frequent or prolonged close contact with such cases are provided with and wear, at a minimum, an N95 respirator, goggles or face shield, and a gown.
(9)Standard describes controls for specific industries (construction, manufacturing, retail/libraries/museums, restaurants/bars, healthcare, in-home services, personal-care services, public accommodations, sports and exercise facilities, meat and poultry processing, casinos).
(10)Only for sports and exercise facilities.
(11)Source control means the use of protective equipment or other measures such as face coverings to prevent the spread of illness from a potentially infectious person to others.
(12)General workplaces must consider physical distancing and occupancy levels.
(13)Client screening in personal services, fitness-related organizations; worker screening in construction, K-12 institutions, higher education, emergency medical services; student screening in K-12 institutions, higher education; screening of all individuals in healthcare.
(14)Healthcare: Whenever an employee provides direct patient care for a patient known or suspected to be infected with COVID-19, the employer must provide the affected worker with gloves, a gown, eye protection (goggles or face shield), and a medical-grade mask or a NIOSH-approved respirator. Glove use also described for personal service providers, childcare and early education, higher education, emergency medical services. [ETS and PS: Veterinary services and EMS have specific requirements for gloves.].
(15)Goggle use described for emergency medical services, healthcare.
(16)Respirator use described for emergency medical services, healthcare.
(17)Employers must clean and disinfect any common areas, high-touch-surfaces, and any shared equipment under the employer's control that an individual known to be infected with COVID-19 used or had direct physical contact with. For exceptional risk workplaces, training is required that includes 'An explanation of contact, droplet, and airborne modes of transmission of COVID-19, including…how employees can take precautionary measures to minimize their exposure.'
(18)Healthcare only.
(19)Emergency Medical Services only.
(20)The standard mentions a hierarchy of hazard controls for the transportation industry.

Control strategies

The four state regulations took varied approaches to workplace controls, but all required employers to utilize controls to the extent feasible and detailed multiple strategies that must be utilized (Table 3). Only the Virginia regulations incorporated the concept of the hierarchy of controls in the discussion of control strategies. Source controls (e.g. masks) were included in the VA-PS, but not in the later VA-AMN, while in Oregon source controls referenced requirements of the Oregon Health Authority. The California and Virginia regulations explicitly linked control strategies to COVID-19 transmission routes. The Virginia regulations delineated controls based on risk category and Oregon required general workplaces to consider physical distancing and occupancy levels in the context of risk levels.

The US-ETS-HC defined controls as droplet and airborne precautions, as per guidelines from the US CDC, and the controls did not vary by risk category, nor did the regulation mention the hierarchy of controls or source controls. The US-ETS-VC focused only on vaccination, testing for COVID-19, and face coverings (or voluntary use of respirators) and did not discuss the hierarchy of controls.

Minimizing sources of infection in the workplace

All of the state regulations and the US-ETS-HC required screening of workers or clients as a means of limiting sources in the workplace. The Oregon regulations are the most specific, requiring client screening in personal services and fitness organizations; worker screening in construction, education, and emergency medical services; student screening in education; and screening of everyone in healthcare organizations.

All of the state regulations and the US-ETS-HC require working remotely as means of limiting sources in the workplace, when feasible; the California regulations include working remotely as a form of physical distancing. All but Virginia required physical distancing as a means of limiting exposure. Only the MI-ETS1 and the Virginia regulations identified limiting occupancy numbers as a control method.

The VA-AMN, CA-ETS2, CA-ETS3, and the US-ETS-VT discuss vaccination as a control strategy. Vaccine mandates were the primary focus of the US-ETS-VT. The CA-ETS2 required employers to inform employees about benefits, including sick and vaccination leave. The CA-ETS3 stated that employees who were not fully vaccinated could request a respirator for voluntary use without fear of retaliation and at employer cost.

All of the state regulations and the US-ETS-HC required hand washing as a control requirement; all but

Virginia describe cleaning and sanitation of surfaces and objects.

Air cleaning and filtration

All of the state regulations required the use of engineering controls, where possible. Ventilation was specifically addressed in the Virginia, California, and Oregon regulations and the US-ETS-HC; in MI-ETS1 ventilation was mentioned only for sports and exercise facilities. Aspects of ventilation discussed in the standards included: increased outside air, use of portable filtration and other air cleaning devices, and filtration within building ventilation systems. None of the regulations, however, prescribed a specific ventilation performance standard nor required upgrades to ventilation infrastructure.

Administrative controls

All of the state regulations and the US-ETS-HC required the use of administrative controls as a means of limiting exposure, including employee training, recordkeeping, and return to work criteria. Contact tracing or case investigation and procedures for reporting exposures are addressed in the California and Oregon regulations and the US-ETS-HC. The Virginia, California, and Oregon regulations and the US-ETS-HC describe medical removal and access to testing at no cost to the employee. Employee access to medical records and data are discussed only in the Virginia and Oregon regulations and the US-ETS-HC, while the privacy of medical records is described in the California regulations and the US-ETS-HC.

Personal protective equipment

All of the state regulations describe the use of personal protective equipment (PPE) as a means of limiting exposure. The MI-ETS1 was the most explicit in requiring employers to provide employees with PPE, including respirators 'appropriate to the exposure risk associated with the job.' As well, the MI-ETS1 states that healthcare employees 'in frequent or prolonged close contact' with known or suspected cases of COVID-19 must be provided and wear, at a minimum, an N95 respirator, goggles or face shield, and a gown. All of the regulations discuss the use of face coverings, but only MI-ETS2 and US-ETS-VC address the use of face shields, gloves, and goggles; Oregon regulations refer to the Oregon Health Authority for face covering requirements. Respirators are discussed in all of the regulations, with the exception of MI-ETS2. The CA-ETSs states that 'N95s and more protective respirators protect the users from airborne disease while face coverings primarily protect people around the user.' In Oregon, respirators are only discussed as a requirement for healthcare settings. Voluntary use of respirators is addressed in the Virginia and Oregon regulations, the CA-ETS2 and CA-ETS3 and in both federal ETSs.

Discussion

Transmission routes

While many in the scientific community recognized the potential for airborne or aerosol transmission of COVID-19 at the outset of the epidemic (Tang *et al.*, 2020; Li, 2021), the US CDC emphasized the role of contact with contaminated surfaces and the projection of respiratory droplets as the primary transmission routes until October 2020, when inhalation of respiratory aerosols was recognized as an important transmission route (CDC, 2020c). The CDC recommendations for workplace health and safety did not change, however, to reflect this additional mode of transmission.

The state regulations mirror CDC's progression from contact and droplet to aerosol inhalation as modes of person-to-person transmission. All of the regulations except the MI-ETS2 describe contact with contaminated surfaces as a source of SARS-CoV-2 exposure (Table 1). None of the state standards considered *only* contact transmission, but the treatment of droplet and airborne transmission was complicated by vagaries in definitions of aerosols and droplets used in the context of respiratory infectious disease transmission. For example, the CA-ETS used the terms airborne droplet, small particle aerosols, and airborne droplet nuclei, but did not distinguish between them in terms of particle size or route by which the particles are taken into the body (e.g. projection onto facial mucous membranes vs. inhalation) and did not consider exposure beyond 6 ft of an infected source. The two US-ETS were the only regulations to define exposure in terms of likelihood, route of exposure (inhalation and contact), and distance from the source (short vs. long distance).

Exposure and risk levels

In general, an individual's inhalation exposure to an airborne contaminant, and therefore risk of adverse health outcomes, is a function of the contaminant concentration in the air, duration of exposure, and breathing rate. The US CDC guidance simplified this time-dependent process, first to a duration of 15 min (CDC, 2020a) and then to a cumulative duration of 15 min over 24 h in October 2021 (CDC, 2020b), neglecting the role of virus concentration in air. The airborne concentration of virus-laden respiratory aerosol in an environment is highly context-specific, determined in part by the number of sources, source strength, source duration, ventilation, proximity, and aerosol dynamics. A number of investigators have attempted to simplify these complex processes to provide

rules of thumb or indicators of risk. Thus, risk can be delineated on the basis of the factors that influence both concentration and time in a workplace.

Such an effort was represented in the early COVID-19 guidance from OSHA (OSHA, 2020a), which defined four risk categories based on proximity to a source (≤ 6 ft for ≥ 15 min over 24 h), frequency of close contacts, whether contacts were members of the public, co-workers or sources known or suspected to have COVID-19, and whether contact involved medical, laboratory, or post-mortem procedures. No guidance was offered for combining these factors to arrive at an exposure level, however.

This approach was also reflected in the VA-ETS, VA-PS, and MI-ETS1 (Table 2). The VA-ETS and VA-PS explicitly identified higher contact frequency and longer contacts to be associated with a higher probability of infection and described numerous factors that could impact the risk level (e.g. tasks, work environment, presence of infected people, etc.), but these descriptions were removed from the VA-AMN in favor of a more general statement that risk was associated with hazards and job tasks that exposed employees to SARS-CoV-2 virus or COVID-19 disease. The first Michigan ETS described the risk in terms of the likelihood and frequency of close contact with either people known or suspected to be infected or with co-workers or the public. The second MI ETS had no risk levels or discussion of risk. The Oregon standards simplified the risk categories to two, where specific workplaces were specified as posing an exceptional risk, consistent with the OSHA 'very high risk' category. Of note, neither US-ETS-HC nor US-ETS-VC discuss risk categories, in contrast to the agency's previously posted guidance.

Control strategies

In occupational hygiene, the hierarchy of controls is an important paradigm that prioritizes control strategies that eliminate or reduce the presence of the hazard in the workplace over those that require changes in worker behaviors or personal protective equipment (PPE). This concept was represented in the early US OSHA COVID-19 guidance (OSHA, 2020a), which discussed the hierarchy of controls for medium, high, and very high-risk levels. In order of priority, these included: worker screening (symptoms and temperature), isolation of suspected cases, engineering controls (e.g. barriers between workers, methods for separating people by 6 ft, ventilation system improvements), administrative controls, and safe work practices (e.g. limiting numbers of workers, separating workers by 6 ft, increased cleaning and disinfection, and wearing face coverings), and PPE (e.g. respirators, gloves, goggles, and face shields) (OSHA, 2020b).

Despite this guidance, the hierarchy of controls is only specifically discussed in the Virginia regulations, although the Oregon regulations discuss the need for a layered approach to controls. Of note, neither US-ETS-HC nor US-ETS-VC discuss the hierarchy of controls, in contrast to OSHA's previously posted guidance. However, while the hierarchy of controls is not explicitly mentioned, most of the control strategies discussed in the early COVID-19 guidance from OSHA were included in the state and federal regulations, including source control through the use of face coverings.

Vaccination was not a strategy considered in the early COVID-19 guidance from OSHA or the US-ETS-HC: When these regulations were developed, vaccines were not yet available, but their use could have been anticipated. In contrast, the US-ETS-VC was singularly focused on vaccine mandates. No US OSHA regulation has ever required vaccination as a condition of work; the BPP standard contemplates Hepatitis B vaccination for exposed workers but allows employees to waive this requirement without reprisal. Similarly, no guidance from the CDC recommends mandatory vaccination for healthcare workers. In addition to vaccine mandates for large employers, the US-ETS-VC required unvaccinated employees to wear facemasks (surgical masks) and undergo weekly COVID-19 tests at the expense of the employee. This shift of the burden to employees is in stark contrast to existing OSHA standards that require employers, with few exceptions, to provide PPE to employees at no cost. For these and other reasons, this standard did not survive legal opposition.

A model infectious disease standard

As US OSHA contemplates the establishment of an Infectious Disease Standard, our review of these COVID-19 regulations suggests some areas that should be considered in rulemaking at the federal and state levels to ensure that workers in all workplaces are protected from infectious diseases. Employers may also consider these suggestions in the development of their own policies and procedures for preventing infectious disease transmission to employees.

We recommend that OSHA and the occupational health community move beyond the classical definitions of airborne, contact, and droplet transmission used by the CDC (Siegel *et al.*, 2007). As discussed more thoroughly elsewhere (Jones and Brosseau, 2015; Tang *et al.*, 2020; Li, 2021), the distinction between airborne and droplet transmission routes is not supported by recent research, nor is it consistent with the physics of respiratory exposures, and the associated exposure measurement strategies used in occupational health. While there remains a need for more research to understand the magnitude of exposure that arises

from droplet spray and to characterize infectious respiratory aerosols (Wilson *et al.*, 2022), there is now enough information to establish a new paradigm (and accompanying vocabulary) responsive to the health risks experienced by workers.

A precautionary approach may be to presume that the inhalation of respirable infectious aerosols is the key transmission route, as the respiratory tract is an effective portal through which a pathogen can access many organ systems to initiate infection; and the presence of respirable infectious aerosols is indicative of the potential for droplet spray and surface contamination. In the alternative, a weight-of-evidence approach could be used to establish the biological plausibility of any particular mode of transmission. Jones and Brosseau (2015) describe one approach for determining the likelihood of disease transmission by inhalation of aerosols; similar approaches could be developed for other modes of transmission.

The probability of transmission and severity of disease vary by infectious organism, exposure scenario, population, and time, among other factors. As a result, a comprehensive regulation should consider all infectious diseases, but enable categorization of risk so that infectious diseases and control strategies can be prioritized. The lack of occupational exposure limits for pathogens has been lamented, but occupational hygiene practice has demonstrated that exposures can be identified, ranked, and controlled through qualitative and semi-quantitative approaches, including control banding (Zalk and Nelson, 2008). As described by Sietsema *et al.* (2019) and Brosseau *et al.* (2021) the source-pathway-receiver framework can help to identify and rank controls. The risk group, which represents both disease severity and availability of preventive or prophylactic treatments, is a useful stand-in for 'toxicity.' Lacking quantitative measures of effectiveness, multiple 'layered' interventions can be considered for higher-risk situations.

Infectious diseases are transmitted to people from other people, animals, and environmental media, so it is difficult to conceive of a workplace where workers would not encounter an infectious disease, beyond working alone at home. Healthcare settings have been a priority for infectious disease standards to date because they serve people with infectious diseases and are subject to some occupational health surveillance. As demonstrated by the state regulations for COVID-19 we reviewed, it is possible to develop regulations that prevent person-to-person transmission of infectious diseases in diverse workplaces.

The mandatory vaccination approach taken in the US-ETS-VC, and putative strategies that shift responsibility and costs to the employee (presumably to motivate vaccination), are problematic. It deviates from similar regulations, like the BPP standard, which requires that employees be offered vaccines but does not mandate vaccination. Adding a requirement for influenza vaccination after hire has not been successful in healthcare settings, while making vaccination a condition of employment can be effective (Babcock *et al.*, 2010). Mandatory vaccination shifts the burden of providing a safe work environment from the employer to the employee, which does not align with the basic premise of the US Occupational Safety and Health Act.

Occupational health professionals, including occupational hygienists, have experience with the development and implementation of occupational health programs, even if infectious diseases are a new hazard for many. An infectious disease regulation should require a written program that includes hazard identification, exposure assessment, interventions that follow an appropriate hierarchy, and continuous assessment of program effectiveness. Tools for completing these steps have been described in the literature: Jones *et al.* (2020) describe a risk-based strategy for selecting PPE, McCullough and Brosseau (1999) describe a control banding approach for selecting respirators for bioaerosol exposures; Sietsema *et al.* (2019) describe a control banding strategy for aerosol transmissible pathogens. The anticipation of a federal regulation will likely motivate substantial innovation in risk assessment and risk management frameworks for infectious disease prevention in the workplace.

Infection prevention and occupational health

Infection prevention and control guidelines often fail to recognize the impact of infectious disease exposure on worker health and safety. Workers may be viewed as important vectors of disease transmission (e.g. patient-to-patient in healthcare settings), but their personal risks are often ignored or downplayed. For example, failure to establish collaborative relationships among public health, infection prevention and occupational health and safety professionals was a core reason for the SARS outbreaks in Toronto whereas such relationships prevented similar outbreaks in Vancouver (Independent SARS Commission, 2007).

The USA experienced similar failures in collaborative decision-making at the state and federal level as well as across professions. Workers whose jobs required close contact with the public, patients, co-workers, or other potentially infected individuals were at higher risk of exposure and infection throughout the SARS-CoV-2 pandemic as demonstrated by retrospective analyses (Chen *et al.*, 2021; Hawkins *et al.*, 2021) but data on occupation or job were rarely collected, reported, or evaluated during the pandemic. Many state departments of health lack expertise in occupational health and safety; the same is true for many healthcare

organizations. Infection prevention and control professionals, and medical professionals in general, have little or no training in workplace health and safety. Even with an overarching US OSHA standard for infectious disease, failure to build better working relationships between occupational health and safety professionals and public health, infection prevention, and medical professionals will likely lead to ongoing high rates of work-related infection during future outbreaks and pandemics.

Conclusions

The challenges of preventing occupationally acquired COVID-19 highlight the need for occupational safety and health regulations that set minimum expectations for employers and facilitate sustainable controls to prevent COVID-19 and other endemic and emerging infectious diseases. Four states took the initiative to issue regulations related to workplace prevention of COVID-19, and while each had strengths, there were also limitations, in particular with respect to aligning workplace risk levels, disease transmission routes, and control strategies.

An OSHA infectious disease regulation should certainly recognize the importance of consulting with the CDC and other public health authorities during outbreaks and pandemics involving novel pathogens. However, OSHA and the employers it regulates should not be required to subscribe to the current infection control paradigm, which is outdated and fails to recognize the potential for aerosol inhalation. Most of the regulations we reviewed failed to consider or address aerosol inhalation and were overly focused on hand and surface sanitation, physical distancing, barriers, and cloth or surgical masks. OSHA should have the power to develop regulations for all workplaces (including healthcare) informed by a modern and up-to-date understanding of infectious disease transmission.

An OSHA infectious disease regulation should require every workplace to develop a written exposure assessment plan predicated on the assumption of aerosol inhalation (at a minimum). Based on experience from the COVID-19 pandemic, OSHA must recognize and address risks and exposure reduction measures for essential industries and workplaces unable to utilize work-from-home or similar methods for limiting person-to-person exposure. Employers should be required to assess employee exposures to both endemic and novel pathogenic organisms in the context of their industry, workplaces, and jobs.

The COVID-19 experience suggests that OSHA must contemplate some important issues not previously considered when planning for pandemic infectious diseases. A few examples include: the likelihood of pre- and asymptomatic transmission, which are not captured by traditional temperature and symptom screening; the role of face coverings, facemasks, and respirators for source control vs. personal protection; the relative effectiveness of dilution vs. local exhaust ventilation in preventing close-range exposure to human-generated infectious aerosols; the role of less expensive, more frequent, and less sensitive rapid antigen tests; whether barriers, face shields, goggles, etc. are necessary or effective at preventing aerosol inhalation; effectiveness, costs, and possible downsides (e.g. antimicrobial resistance and chemical hazards) of frequent surface sanitization; among others.

California OSHA was the only US regulatory authority with a workplace health and safety standard for aerosol transmissible infectious diseases prior to the COVID-19 pandemic, which applied only to healthcare and related workplaces. The OSHA programs in Virginia, Michigan, Oregon, and California should be recognized for their rapid response to the pandemic with new regulations for healthcare and all workplaces. Their experience illustrates that ETSs can play an important role in assuring worker health and safety, but also highlights the limitations of short-lived, impermanent regulations. For most of the pandemic most of the US workforce did not have an OSHA regulation protecting them from aerosol- and contact-transmissible infectious diseases. We urge US OSHA and all state OSHA programs to focus in the near future on developing an all-encompassing workplace infectious disease regulation for both endemic and novel organisms that addresses all important routes of transmission.

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Conflict of Interest

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Data Availability

Copies of the standards reviewed in this paper may be obtained by email request to the corresponding author.

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