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REVIEW ARTICLE

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COVID-19 as an occupational disease

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Abstract

The impact of coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 permeates all aspects of society worldwide. Initial medical reports and media coverage have increased awareness of the risk imposed on healthcare workers in particular, during this pandemic. However, the health implications of COVID-19 for the global workforce are multifaceted and complex, warranting careful reflection and consideration to mitigate the adverse effects on workers worldwide. Accordingly, our review offers a framework for considering this topic, highlighting key issues, with the aim to prompt and inform action, including research, to minimize the occupational hazards imposed by this ongoing challenge. We address respiratory disease as a primary concern, while recognizing the multisystem spectrum of COVID-19-related disease and how clinical aspects are interwoven with broader socioeconomic forces.

KEYWORDS
COVID-19, occupational, respiratory disease

1 | INTRODUCTION

The evolving coronavirus disease 2019 (COVID-19) pandemic continues to impose a major burden and toll on workers, even as vaccination efforts accelerate. The intersection of the pandemic with the workforce is a complex topic involving historic forces, issues of vulnerability and susceptibility, a dynamic understanding of transmission and related occupational hygiene, and multifaceted issues of testing for infection and related return-to-work challenges. To make that complexity digestible, this narrative review is intended for a general audience, and written to be easily accessible and applicable to an interdisciplinary range of perspectives, including those who may have little initial appreciation of the topic. In that vein, we are oriented therein to stimulating discussion and awareness, rather than to dissecting any particular aspect of this comple topic in great detail.

1.1 | History repeats: Disasters' toll on the workforce

Major epidemic and pandemic respiratory infections have historically brought devastation to the general population, often with a disproportionate impact on workers, that results in profound but frequently overlooked occupational morbidity and mortality.[1] Occupational health risks have, in recent history, been relatively unanticipated or dismissed during times of crisis, including the present COVID-19 pandemic,[2,3] previous influenza and coronavirus pandemics (such as the severe acute and Middle Eastern respiratory syndromes [SARS and MERS, respectively]), and 2001 US World Trade Center (WTC) bombing and subsequent recovery work.[4] A range of new and lingering pulmonary manifestations were reported after those public health crises, including reports of persistent reticular radiographic abnormalities and lung function deficits in patients infected with SARS and MERS and a range of pulmonary manifestations in WTC-exposed workers.[5-8] The current pandemic may, likewise, pose long-term risks for the respiratory health of workers, compounding the illnesses and deaths tallied each day.[9] In such catastrophes, badges of heroism affixed to responders may hide injuries inflicted if not outright deaths, some of which might have been preventable and could be prevented in future disasters.

It may be misleading to describe the present situation with COVID-19 as unprecedented. A century ago, the 1918–1919 influenza pandemic killed approximately 75 million people worldwide within the first 2 years of its onset.[10] There was a socioeconomic gradient, with higher mortality in the poorer sectors of the population, and those working in overcrowded conditions, such as naval seafarers, were at increased risk. The first described occupational group affected with COVID-19 was animal wholesale workers in Wuhan. The situation was similar to the earlier avian (H5N1) and H1N1 influenza, and SARS, where concerns about occupational infection arose among workers in healthcare and agriculture, those in crowded workplaces (e.g., cruise ships and meat packing plants), and those designated as "essential" workers, that is, workers deemed critical to societal infrastructure that were often not given the choice or the means to protect themselves. Meat packing is a prime example of where a constellation of problematic conditions elevate risk for the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[11]

The vigor and effectiveness of government intervention has varied widely,[12] as has the citizenry's willingness to conform to policy and guidance.[13] However, as noted further below, the range of workers affected by COVID-19 has grown quickly. As we continue to care for COVID survivors—many of whom have suffered acute respiratory distress syndrome and thrombotic complications, we are only beginning to learn what proportion of individuals are at increased risk for developing residual or progressive pulmonary fibrosis[5,14] and pulmonary vascular disease[15] as well as other fatigue and dyspnea-associated conditions such as myositis postinfection.[16] However, these complications appear to be disturbingly common[17] and thus may further diminish work capacity. As the pandemic progresses, there is concern for lingering or even chronic symptoms beyond the respiratory system and with major quality of life implications, based on recent data.[18] Lessons drawn from previous and current pandemics and disasters must be learned, and inform future responses to these inevitable events.

1.2 | Vulnerability and susceptibility at work in the context of COVID-19

Essential workers likely face the highest risk from exposure to SARS-CoV-2.[19] These include workers in healthcare, protective services (e.g., police officers, correctional officers, and firefighters), office and administrative support (e.g., couriers and messengers, and patient service representatives), social services (community health workers and some social workers), and maintenance workers (e.g., plumbers, septic tank installers, and elevator repair).[20,21] Accordingly, initial studies are reporting higher incidence rates of SARS-CoV-2 among healthcare workers (HCW).[2,22,23] Elevated incidence rates are likely, but less well documented for other essential workers. Some suggestive examples exist—a Swedish national study showed that taxi drivers and bus drivers—both with high degrees of social contacts, have been at increased risk.[24] Beyond simply exposure to virus-laden aerosols (VLA, wherein SARS-CoV-2 is suspended in air for prolonged periods of time), the COVID-19 pandemic has unmasked major socioeconomic factors that contribute to higher rates of infection, severity of illness, and risk of death. Disparities in illness and death among workers are linked to a number of interrelated factors, including the nature and hazards of the jobs performed as well as baseline health conditions and socioeconomic factors. These factors revolve around issues of vulnerability (increased likelihood of exposure) and susceptibility (increased likelihood of adverse clinical consequence; Table 1). While the influence of these factors has been most extensively documented in the United States, as discussed further below, these factors are very likely to operate internationally

TABLE 1 Worker vulnerability and susceptibility in the context of COVID-19

Vulnerable workers	Susceptible workers
Definition: Workers at higher risk for Covid-19 due to *greater likelihood of higher exposure*	*Definition*: Workers at *higher risk for COVID-19 (or worse outcomes)* at any level of exposure
Factors:	*Factors:*
Hazardous work characteristics: • Exposure to infected aerosols (especially amongst essential workers or those unable to work from home)[26] • Lack of appropriate or properly fitted personal protective equipment (PPE), or occupational safety training • Densely populated, enclosed, or poorly ventilated workplaces[27]; difficulty distancing from VLAs • Prolonged face-to-face or physical contact or where social distancing cannot be practiced	Demographic characteristics: • Elderly • Male sex Co-morbidities: Obesity, hypertension, diabetes mellitus, cardiovascular disease, kidney disease, cerebrovascular disease, COPD, and immunosuppression Co-exposures: • Smoking/environmental tobacco smoke exposure • Residence or work in high particulate air pollutant environments • Limited access to healthy foods and physical activity
Cross-cutting factors that may confer or compound both vulnerability and susceptibility	
Enhance Exposure to SARS-CoV-2:	
• Residence in densely populated neighborhoods • Residence in homes that are overcrowded, multigenerational or without access to running water • Dependence on mass or shared (crowded) transportation	
Predispose to poorer health outcomes:	
• Low socioeconomic status/underprivilege • Language and/or communication barriers • Limited access to paid sick leave and healthcare	

Note: These categories are not mutually exclusive (an individual may have both), and "cross-cutting" characteristics may contribute to both.

Abbreviations: COVID-19, coronavirus disease-2019; COPD, chronic obstructive pulmonary disease; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; VLAs, virus-laden aerosols.

and data are emerging to support their broad applicability in the context of COVID.[25]

Vulnerability is common among workers who face exposure to COVID-19 because they conduct operations and services considered essential. Even though many of these jobs place workers in close contact with infected co-workers and the public, enhancing their potential for exposure to SARS-CoV-2, the provision of minimally effective personal protective equipment (PPE) and adoption of other more effective preventive measures were delayed (in many regions) for many weeks after onset of the pandemic.

A report from New York City[28] confirmed that the mortality rate among African Americans and Latino patients (92.3 and 74.3 per 100,000 inhabitants, respectively) substantially exceeded that of Caucasian and Asian cases (45.4 and 25.3 per 100,000, respectively). As is often the case, ethnicity and race often conceal unmeasured or uninvestigated socioeconomic (including occupational), as opposed to biological, factors. Accordingly, the higher SARS-CoV-2 exposure risk incurred by people of color has recently been demonstrated in a recent study.[29] Low-income workers in the United States—who are disproportionately African American and Latino—are more likely to work in jobs with higher exposure and fewer opportunities for social distancing, and also bear a higher burden[30] of the susceptibility factors described in Table 1. Further, immigrants with multi-generation living arrangements and fewer opportunities for social distancing may be at increased risk for COVID-19. The disproportionate impact associated with ethnicity and race can be severe, with some groups experiencing up to nine-fold higher population-adjusted rates of COVID-19.[31] Disturbingly, Latinos markedly increased as a proportion of total COVID-associated deaths (16%–26%) in the United States from May to August 2020,[32] suggesting that early concerns of vulnerability and/or susceptibility amongst this group were not met with sufficient protective adjustments.

In particular, the severe impact of the pandemic upon the healthcare workforce (especially low income workers)[2,3,22] has

become clear. In the United States, the largest number (around 1.3 million) of HCW are nurse assistants or home/personal care aides, with direct patient care.[20,33-35] Nearly a million more provide "essential" nondirect patient care services through work in housekeeping, laundry or food services where they also face substantial infection risk. Correctional facilities also provide health care in a particularly hazardous setting.[36] Close to a quarter of HCW at risk for exposure to SARS-CoV-2 have medical conditions that increase the probability of poor COVID-19 outcomes.[37] Nearly 1 in 10 low-wage workers in the United States report that they are in fair to poor health.[37]

It was only after the economic downturns became an undeniable reality, even in the richest countries of the world, that these disproportionate effects of the pandemic on higher risk occupational and socially disadvantaged groups began to receive some attention, mostly in editorials in several medical journals[23,38-40] and in news reports from the lay press.[41] Many workers entered the pandemic in low-wage jobs, and some experienced an additional loss of income, even if they remained employed, due to diminished work hours and hourly pay. Approximately 80% of low-income workers are paid hourly, and around 43% are employed in small firms with fewer than 25 people—with employers for whom survival during the crisis is likely most marginal.[42] The precarious financial circumstances of many workers decreases their ability to afford out-of-pocket healthcare costs. Notably, uninsured Americans are twice as likely to avoid seeking treatment for COVID-19 because of cost concerns.[37]

These findings underline the need for increased attention to reducing risk for these workers during the pandemic. Mitigation efforts include the following: improved administrative and engineering preventive controls (discussed below), ensuring access to Workers' Compensation benefits, adopting or expanding sick leave benefits, and providing occupational and general health insurance coverage (ideally low- or no-cost) for all workers. Many of these compensatory mechanisms may be unrealistic in low- and middle-income countries (LMICs) where resources are particularly scarce. However, it should be noted that some LMICs, including, for example, Thailand and Cuba, have done remarkably well during the pandemic perhaps in part due to strong implementation of public health measures in spite of limited resources.

Key research gaps in this area are (1) systematic observational studies, with socioeconomic indicators (beyond ethnicity/race alone) that include industry and occupation descriptors (see below); (2) occupation-specific exposure assessments and verification of effective safety measures (including but not limited to PPE); and (3) evidence-based prevention measures tailored to worksites according to level of risk for exposure to SARS-CoV-2.

1.3 | The role of occupational hygiene in reducing the risk of direct exposure to SARS-CoV-2

When countries loosen social distancing and other restrictions and there is increased potential for exposure in a multitude of industries and occupations, strengthening the fundamentals of occupational hygiene is critical.[43] There are four main techniques for preventing workplace exposures to SARS-CoV-2.[44] These include: (1) exposure elimination, (2) engineering controls, (3) administrative controls, and (4) PPE. Several national and international organizations have offered guidance in this regard.[45-49]

Reducing exposure is of course critical to reducing infection and the still unknown long-term lung sequelae of COVID-19.[5,15] These approaches must be informed by relevant laws and policies guarding against discrimination and being sensitive to disabilities. Recognizing that reasonable concerns for cost and burden to employers pose challenges that should be considered, protection of the worker remains paramount.[50] Unfortunately, the viability of worker protections varies widely across the globe. LMICs, and even more well resourced nations at times, may lack sufficient sanitizing supplies, PPE, and other administrative or engineering protections in health care facilities, and likely many workplaces,[51] and broader policies protecting workers with a holistic perspective are often quite weak.[52]

Regardless, occupational SARS-CoV2 exposure elimination fundamentally involves lowering community transmission and emerging vaccination efforts will greatly contribute to achieving this goal.[53] In parallel, preventing contagious workers from entering the workplace and increasing telecommunication and other options for work from home and otherwise maintain physical separation whenever possible. Pre-placement testing and screening individuals for symptoms and signs of COVID-19, excluding those screen-positive from contact with the uninfected, are important strategies. Unfortunately, these do not exclude infected individuals without signs or symptoms, who can only be identified by additional screening via medical testing; fortunately, rapid on-site screening is becoming more feasible and common, though false negatives remain a concern[54] (as discussed below).

Engineering controls are designed to be independent of behaviors and are generally more effective than PPE in protecting workers. Physical barriers, such as plastic barriers between workstations, can block some VLA and prevent direct person-to-person contamination. Ventilation, in the form of effective VLA removal or providing VLA-free air, can also prevent worker exposure, and its importance is increasingly appreciated.[55,56] Another example of an engineering control that may reduce exposure to VLA is ultraviolet germicidal irradiation (UVGI), though its effectiveness for SARS-CoV-2 has not been established. Further research into the efficacy of each of these controls for workplace VLA exposure is needed, especially given lingering controversy[57] amidst the emerging evidence that SARS-CoV-2 is spread by aerosol and not simply droplet.[58] As consensus around aerosol transmission consolidates and mitigation approaches are debated,[55,59,60] pitfalls of false reassurance from distance alone and/or barriers that do not block aerosols (which simply bypass barriers) need increased investigation via novel social and natural science collaborations. In doing so, portrayals of transmission risk as simply linked to droplet versus aerosol mode, itself part of a continuum of physicochemical properties linked to virus

burden,[61] should be tempered and subject to careful science communication.

Administrative or work practice controls depend on high levels of adherence to be fully effective. Examples include social distancing, staggered staff schedules, requirements for facemasks and hand hygiene, protocols to decrease hazardous activities such as touching contaminated surfaces, and surface cleaning and disinfection (although the true propensity for surface transmission of SARS-CoV-2 has been much debated and needs ongoing investigation).[62] Proper infection control training and practice have been shown to decrease risk of SARS-CoV-2 infection.[2]

PPE, though most burdensome for the worker, and rightly placed at the bottom of the traditional exposure control effectiveness hierarchy, is still important to reduce risk of occupational infection and transmission of SARS-CoV-2.[2,23] Recent data show that proper PPE (together with proper training, and ongoing vigilance) can be very effective[63] but inconsistent or conflicting policies and poor training likely reduces its effectiveness, and can be a source of stress for workers.[64] Goggles or face shields, gloves, and gowns/aprons/suits, when properly applied, confer protection against droplet sprays and contaminated surfaces.

Respiratory protection to prevent inhalation of airborne respiratory droplets is also important. In well-ventilated low prevalence contexts, standard surgical masks offer reasonably adequate protection, but when there is significant concern for airborne exposure, N95 respirators are recommended. Earlier in the pandemic, the need for N95s was most associated with aerosol-generating procedures, but given the increased evidence around aerosol transmission more generally, N95 respirators are advisable when feasible given recent evidence that a high percentage of SARS-CoV-2 infection may occur in those healthcare workers wearing surgical masks[65] although a prior trial in the context of influenza surprisingly showed non-inferiority for surgical masks.[66] N95s are required to capture 95% of airborne particles. The KN95 designation in China is also defined as 95% filtration. In Europe, the equivalent is FF2, which are required to capture 94% of airborne particles. However, the testing standards for demonstrating these filtration percentages vary by jurisdiction. Most of the inhaled particles are from inward leakage around the edges of the respirator. Thus, at least annual fit testing is important, despite the temporary suspension of this requirement during the pandemic in some countries. Other types of respirators can also be used, such as elastomeric respirators and loose-fitting powered air purifying respirators (PAPRs). An advantage of PAPRs is that they do not require fit testing, and there is some evidence of greater protection.[67] The World Health Organization (WHO) has provided guidance in this regard,[68] which is updated periodically. Notably, there has been increasing attention to cloth-based masks and face covering, which from a practical perspective are attractive, widely used in nonoccupational public settings, and in many cases much more effective than previously believed.[69] However, given the variability and still modest evidence base, these have not widely been recommended in an occupational setting.

1.4 | Minimizing risk of airways disease from cleaning products

As noted above, attempts to control the spread of SARS-CoV-2 justifiably include use of cleaning and disinfecting products, which quickly escalated in not only health care but other workplaces (e.g., in retail and services), public settings, and homes. As with all occupational protective strategies, recommendations from health authorities for cleaning and disinfecting to eliminate SARS-CoV-2 from environmental surfaces should include direction to employers to provide workers' training on the proper use, and the hazards of cleaning chemicals.[70] These hazards include respiratory effects such as: (a) acute inhalation injuries (e.g., irritant-induced asthma) from accidental spills or inappropriate mixing of cleaning products; (b) occupational asthma from sensitization to agents such as enzymes or quaternary ammonium compounds that may be contained in all-purpose cleaners; and (c) exacerbation of airways disease (e.g., asthma or chronic obstructive pulmonary disease) or new cases of such disease, both of which can occur over time even with accident-free ("as directed") use of cleaning products.[71,72] Of concern is a 20% increase in calls to US poison control centers linked to cleaning and disinfecting products during January–March 2020 compared with the same period in 2019.[73] The largest reported increases were for inhalation incidents, cleaning products with bleach, and disinfecting nonalcohol products and hand sanitizers, particularly in early in March 2020 when stay-at-home orders began. Related respiratory concerns, as well as dermatological complaints, have manifested in diverse geographic regions across the globe.[74-76]

There is an ongoing need for government agencies, companies, and private organizations to communicate recommendations for safe and effective use of cleaning and disinfecting products to help achieve the dual goals of preventing both COVID-19 infection and secondary occupational airway diseases. As just one example, hazards due to cleaning products can be reduced with use of wiped instead of sprayed products; when possible, with use of robots; and with appropriate ventilation and education on these and other occupational hygiene practices. The magnitude of this pandemic points to an urgent need for research to improve understanding of the role of specific cleaning agents and procedures in causing and exacerbating both acute and chronic airway disease, and the control of such exposures. These data should be obtained in conjunction with studies of the effectiveness of cleaning products and procedures to eliminate infectious agents from environmental surfaces and aerosols. Such research will add to efforts, increasingly important as the COVID-19 pandemic endures, to distill the complexity surrounding the risk of cleaning and disinfection products on lung health.[65]

1.5 | Targeted testing of workers

It is clear that a large proportion of the workforce, across a variety of occupational sectors (especially essential workers), are at increased risk for COVID-19 (Table 1). Targeted SARS-CoV-2 testing should

focus on these workers, using evidence-based screening algorithms to prioritize tests among the most exposed, vulnerable and susceptible workers (described above), as well as the symptomatic ones. The role of testing other asymptomatic but high-risk groups[77] remains uncertain. Testing may be reasonable in these groups, if prioritized by public health departments or clinicians, for reasons such as public health monitoring, sentinel surveillance, or screening of other asymptomatic individuals according to state and local plans.[78] The latter may, however, change frequently in response to rapidly changing local circumstances during the pandemic. Policy solutions are needed to eliminate financial barriers to testing uninsured or underinsured asymptomatic at-risk workers. Targeted testing needs to be used in conjunction with other exposure control measures, and with appropriate use of information technology. The WHO has provided additional perspective on this topic.[79]

That said, though a large number of SARS-CoV-2 tests are currently available, some are inadequately studied, with high rates of false-negative results early in the course of infection when the viral load in the upper respiratory tract is low.[80] Choosing the appropriate test and testing time window,[81] while acknowledging variable or uncertain diagnostic performance that is compounded by difference in population prevalence, is therefore crucial. A recent statistical model shows that effective molecular surveillance depends less on the analytical limits of detection, but largely on accessibility, frequency of tests, and speed of reporting.[82] Tests targeting nucleic acids or viral antigens in respiratory tract specimens are useful for diagnosing infection in workers. Serological tests may be useful for retrospective diagnosis of individual cases, in public health or workplace surveillance[83] but precise operating characteristics of these tests in this context remain uncertain. Most importantly, the potential of SARS CoV-2 antibodies to uniformly prevent related disease remains to be demonstrated.[84]

Workers may prefer sample collection venues outside the hospital, such as drive-throughs/booths, mobile laboratories, or systems catering to home or workplace, such as nucleic acid- or antigen-targeting self-test kits[85] or fingerstick blood samples for serologic tests. Smartphone-based devices[86] and rapid point of care serologic tests will likely soon be available.[87] With any of these, however, both specimen and test methodologic quality are variable, leading to significant risk for misleading information.

1.6 | Return-to-work strategies

As the aforementioned testing strategies improve and workplaces reopen, establishing practices that promote worker safety, maintain jobs and assure confidentiality are essential to protect all workers, including those most vulnerable to infection. Workplace return-to-work plans should: (1) assess the risk unique to specific workplaces and jobs[88]; (2) implement infection protection strategies (described above); and (3) develop evidence-based policies to identify and isolate individuals with suspected or confirmed infection, while allowing previously infected individuals to return to work after self-isolation.[89] Employers should consider applicable recommendations for workplace protections and relevant guidance on protecting workers' rights. External factors such as background community transmission, increasing vaccination rates, and healthcare system capacity influence governmental guidance on reopening. Workplaces should stay abreast of these local trends particularly as many regions have not yet experienced transmission rate reductions.

Return-to-work policies need to be stratified according to worker exposure risk levels,[88] which vary by industry and ability to distance and control exposure to infected individuals. They also need to take into account relevant up-to-date background disease prevalence and test performance characteristics. National and regional recommendation and policy (e.g., those of the Centers for Disease Control and Prevention, in the United States)[89] need be used as fundamental guidance. However, as with all such guidance, these are created as a practical balance between the strongest worker protection and the need for solutions that allow the workplace to operate at reasonable efficiency without prohibitive cost. Therefore, some tailoring to circumstance, while still being attentive to such high-level guidance, may be in the workers' best interest especially in countries or regions where guidance is outdated or where there are multiple guidelines that are in conflict. Workplaces with higher risk have a greater imperative to provide workers with more substantial administrative and engineering controls and PPE, and to facilitate routine symptom screening, testing for case identification, promptly isolating suspected new cases and close work contacts of infected workers and, increasingly, vaccination efforts. Lack of suitable accommodations may force the return of asymptomatic exposed essential workers, likely increasing the risk of infection for others. Of note, the true infectivity of an asymptomatic worker wearing appropriate PPE including a respirator is still unclear. Given the uncertainties, all workers with and without previous infection should be considered at risk and subject to universal workplace standards. Counseling patients in this regard is important,[90] but such frameworks may place disproportionate responsibility on the individual and should be adopted cautiously.

As was the case previously with SARS,[6] pulmonary sequelae of COVID-19 have begun to be reported.[5] Postinfection evaluation will be necessary for many individuals, and return-to-work issues will likely differ for workers with either related functional disability (whether temporary or permanent) or those with pre-existing chronic lung diseases. In doing so, sensitivity to psychological and neuropsychiatric consequences is also critical.[91] An evaluation of work capacity and ability to wear PPE will be necessary for some, and for those whose infection and resultant disability are assessed to be work-related, workers' compensation guidance should be established and supported. Importantly, the utility, cost-effectiveness, and sustainability of the different recommendations to protect workers[47,92-94] needs to be monitored.

1.7 | Incorporation of industrial and occupational data into public health surveillance and healthcare information systems

Given the importance of occupation as a COVID-19 risk factor, responding effectively to the epidemic requires industry and

occupation (I/O) data on cases and contacts. Collecting I/O and employer data can help identify and control hotspots, provide information about patterns of disease, and inform intervention efforts to blunt future waves of disease; Italy has provided an informative model for consideration.[95] Benefits may include understanding seroprevalence of antibodies against SARS-CoV-2 among high-risk groups, which may be lower than anticipated[96] and thus counter overly optimistic predictions of herd immunity.

Despite initial delays in realizing the increased occupational risks of infection, the US Centers for Disease Control and Prevention (CDC) is now recommending collection of I/O data in confirmed or probable cases. The new case report form[97] captures structured information on HCW, including occupation and job setting (e.g., long-term care). I/O data can only be collected for potentially exposed (non-HCW) workers if the interviewee or interviewer considers the work setting "essential," which is not precisely defined and, despite available guidance,[98] substantial I/O data for COVID-19 cases continue to go uncollected. This problem is likely to be more severe in countries that lack effective public health infrastructure, and/or economic resources for adequate implementation.

Regrettably, the current pandemic follows a long tradition of incomplete occupational illness surveillance in most countries, including the US Data sources commonly used for occupational illness surveillance (e.g., national surveys, workers' compensation data) are deficient in multiple ways,[99-101] the most important of which, for COVID-19, are timeliness and both socioeconomic and geographic granularity. The extent to which electronic health record (EHR) data collection[102] has improved the situation remains suboptimal despite improvements in recent years.[103] A variety of systems, tools, big data platforms and apps[104,105] present opportunities to enhance occupational data collection, characterize, and address relationships between COVID-19 and work, and inform the response to the current and future pandemics, yet require substantial privacy controls and voluntary buy-in.[106,107]

When clinicians and public health officials collect data on industry, occupation, employer, and working conditions, they have the ability to (1) notify employers that an employee has tested positive, (2) help develop best practices for keeping workers safe, (3) share guidance on reducing workplace transmission,[47] (4) conduct contact tracing and detect workplace outbreaks, (5) reduce transmission from the workplace to the home, (6) inform workers who test positive of their rights, and (7) evaluate the impacts of varying social distancing guidelines. Enhanced data collection also requires policies and practices that protect workers' rights. A strong and equitable response will protect workers' privacy, financial well-being and health.

2 | CONCLUSION

Workers in the global struggle against COVID-19 have been lauded as heroes, who appreciate this sign of respect. However, as has often been the case in past disasters, the designation as heroes can be associated with an unwanted passport to martyrdom. In addition to recognition for the contributions they make, workers want a safe work environment—a legal right in many countries. Rapidly emerging vaccines promise to attenuate the burden of COVID-19 on the workforce, but the timeframe and ultimate effectiveness of this welcome development remain uncertain, and broad vaccine availability in less well-resourced communities may be delayed for quite some time. Therfore, we urge attention to the key issues we have highlighted (Table 2), so that we can protect those whose work in the pandemic puts them at significant risk. In addition to our praise, respect in the form of optimized protective measures is what these workers want and deserve. And, as the current pandemic hopefully becomes better controlled, the world must prepare for subsequent disasters such that the occupational safety of frontline responders becomes a priority.

TABLE 2 Take-home points to enhance support and protection of workers in the context of COVID-19

1. Infectious pandemics such as COVID-19 have precedent for severe impact on workers, especially in terms of respiratory disease. Workers in general, and essential workers particularly, are more highly exposed to SARS-CoV-2 than the general population, and experience a greater risk of respiratory disease.
2. Factors conferring risk of exposure, vulnerability and susceptibility compound the impact of COVID-19 on workers, and these factors are strongly associated with socioeconomic status; essential workers being disproportionately low-income confers a significant disadvantage.
3. Some occupational interface with the virus is of course inevitable, and understanding the fundamentals of occupational hygiene is critical in the context of COVID-19.
4. There is an ongoing need to communicate recommendations for safe and effective use of cleaning and disinfecting products to help achieve the dual objective of preventing both COVID-19 and secondary occupational airway diseases.
5. Targeted SARS-CoV-2 testing should use evidence-based algorithms to prioritize tests amongst the most exposed, vulnerable and susceptible workers. Workplaces should establish a return-to-work plan that is tailored to specific workplaces and jobs, implements proper infection protection, and can efficiently identify and isolate individuals with likely infection.
6. Industrial and occupational data must be incorporated into public health surveillance and healthcare information systems.
7. Healthy workers should be afforded as much careful and appropriate protection as any others. More than accolades, workers want and deserve a safe environment in which to do their jobs, which is achievable by giving due attention to the key issues highlighted here. We must neither underestimate the risk of nor be unprepared for such catastrophic events.

Abbreviations: COVID-19, coronavirus disease-2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

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