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COMMENT

The COVID-19 pandemic: a moment for exposure science

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As COVID-19 devastates health and fundamentally alters daily activities around the world, we find ourselves in a watershed moment for exposure science. We call on exposure scientists to utilize our collective expertise in this rapidly changing environment. By applying our core principles—including identifying vulnerable populations, elucidating source to receptor pathways, designing interventions in the context of the hierarchy of controls, and communicating effectively about exposures and risks—our field can significantly contribute to minimizing the individual and population-level public health impacts of this crisis.

Exposure scientists can contribute critical expertise to identify highly exposed subpopulations for targeting interventions. While we all can be exposed to SARS-CoV-2, there are distinct subsets of the population who face a disproportionate burden of exposure to the virus. As with many other agents, occupational exposures are significantly higher than nonoccupational exposures [1]. Health-care workers, grocery/pharmacy/retail workers, sanitation workers, janitorial/cleaning staff, and delivery workers have increased likelihood of exposure. The built environment also plays an important role, as people who live in more crowded homes or buildings or more densely populated communities have an increased likelihood of exposure. Lower-income and minority populations are more likely to be both occupationally exposed and to live in higher-risk residential settings so are of heightened concern.

Exposure scientists can also help understand differential risk given similar SARS-CoV-2 exposures, whether related to population characteristics or co-exposures. For example, evaluating critical windows of exposure across the life course matters, and with this virus it is the elderly with the highest risk, a fact compounded by the fact that many are living in high-density senior housing. In addition, evaluation of co-exposures and mixtures have direct relevance. For example, air pollution influences many of the same health outcomes as SARS-CoV-2 and has been associated with higher COVID-19 mortality rates in recent studies [2, 3]. A history of exposures to cardiopulmonary toxicants in the environment or workplace may also increase severity of health outcomes. Evaluating the combined exposures to SARS-CoV-2, other respiratory toxicants, and socioeconomic vulnerabilities (e.g., food deserts, limited access to medical care) can help understand the relative contributions of different risk factors and direct mitigation efforts.

Exposure scientists can leverage and deploy our tried-and-true tools as well as innovative technologies to predict exposure patterns and inform control strategies. Job-exposure matrices can be applied to identify high-risk workers. New smartphone technologies can be developed, such as the app used in South Korea and Singapore, which alerted individuals of potential contact with the virus to trigger testing [4]. Such technology comes with important privacy concerns but is an example of how sensors and metadata may support exposure surveillance and infection prevention strategies. In addition, new genomics approaches and rapid data sharing have allowed for near real-time tracking and spatial visualization of disease dynamics and tracing.

Exposure scientists can design scientifically based mitigation strategies. Many of the recommendations for individual actions we can take to protect ourselves from SARS-CoV-2 are fundamentally grounded in basic principles of exposure science. Physical distancing is based on concepts of particle fate and transport. Decisions about using face masks and gloves hinge on the degree to which viruses can penetrate various materials, proper fit of personal protective equipment (PPE), and how PPE usage influences personal behaviors. Issues around ventilation of occupied areas and

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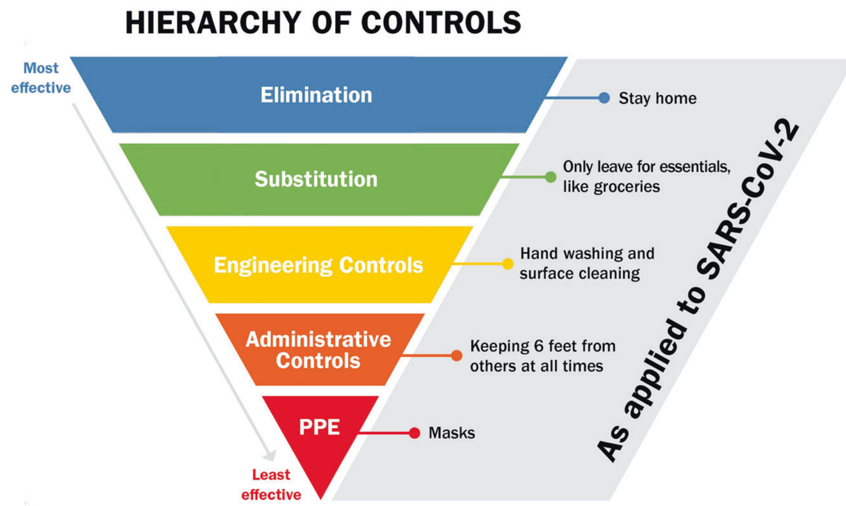

Fig. 1 Hierarchy of controls and application to SARS-CoV-2.

dermal contact of contaminated surfaces in conjunction with hand-to-face behavior are also informing discussions around exposure reduction.

Broadly, people are recognizing that intervening to reduce the probability of exposure is an ideal strategy to reduce health effects, a fundamental tenet of our field. Exposure scientists can communicate to the public the potential benefits of control strategies by placing them in context of the hierarchy of controls (Fig. 1). Elimination of the virus is challenging, and until we have a vaccine, this can only be achieved by isolating oneself; substitution of usual behaviors with different ones will reduce exposures. Engineering controls, which aim to reduce or remove the hazard, can be achieved by inactivating SARS-CoV-2 with disinfectants like soap and alcohol. Administrative controls, like social distancing in the workplace and limiting building occupancy, can also be used to minimize risk. PPE is the "last resort"—the option we use when the exposure cannot be managed from an engineering, technological, or administrative approach, and contact with the agent cannot be avoided. Hence, recommendations to wear a mask when one cannot remain 6 feet from others, such as at a grocery store, is highly advisable.

As in many exposure contexts, the hierarchy of controls differs for those occupationally exposed. Professionals who take care of COVID-19 patients in hospitals and health-care settings cannot eliminate exposures, and therefore need to utilize PPE to protect themselves [5, 6]. Exposure science takes on heightened importance given the short supply of proper respirators and masks and can serve to evaluate efficacy of alternative PPE products before accepting them for common use in high-risk settings and can inform decisions about allocation of PPE among health-care workers versus the general public.

Exposure scientists must be vocal, timely, and science-based in translating the state-of-the-art in exposure science to support immediate strategies for individual and public health actions. As with climate change or any other complex topic, the messages need to be simple and clear, repeated often, by a variety of trusted sources [7]. People do not need to hear what the 95% confidence interval is for a viral exposure dropping by a given percentage as a function of distance. They need to be told to stay 6 feet apart. They do not need data on dominant exposure pathways given frequency of hand-to-face activity. They need to be told not to touch their faces. In addition, when communicating with the public, explaining the "how" of each control strategy is just as important as the "why". We have years of experience and knowledge showing that improper implementation can inadvertently increase exposure.

Recommendations must be made with imperfect data specific to SARS-CoV-2, yet they can also be grounded in many years of science and experience from the field. Those recommendations can, and should, be modified when new data become available and we adjust our priors. The world also needs insight about which exposure scenarios are not genuinely risky. For example, accepting a package from a delivery driver or takeout from a local restaurant confer low exposure risks, based on half-lives of the virus on surfaces [8], and are manageable with some simple precautions.

Exposure science also needs to be anticipating, understanding, and communicating about the myriad other exposures that are changing as a consequence of SARS-CoV-2. Ambient air pollution is dropping during this time of stay-at-home orders, but we are spending more time inside our homes—what does that mean for personal exposures? How are our altered activity patterns influencing exposures to chemicals in consumer products? What are the exposure and health implications of various actions taken to reduce the spread of SARS-CoV-2, related to the virus itself and other exposures? When we resume activity, how will our exposure to outdoor air pollution and green space change? Furthermore, other crises are around the corner, and exposure science needs to anticipate and help prevent them. This includes helping to identify links between the current pandemic and the equally critical topic of climate change.

Once we are past this crisis, which may ultimately come when a vaccine is developed and broadly administered, it will be tempting to celebrate the vaccine and to dispense with all of the exposure-reducing activities that helped to “flatten the curve”. Those of us in exposure science, and in public health more generally, need to continue to amplify the primary role that exposure science played and will continue to play in the prevention and mitigation of adverse exposures and human health protection in this pandemic and the future challenges we face.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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