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Active Surveillance of Engineered Stone Workers Facilitates Early Identification of Silicosis: A Discussion of Surveillance of Occupational Lung Diseases

Sheiphali A. Gandhi, MD, MPH[1], **Amy Heinzerling, MD, MPH**[2], **Jennifer Flattery, MPH**[2], **Jane C. Fazio, MD**[3], **Asim Alam, MD, PhD, MPH**[4], **Kristin J. Cummings, MD, MPH**[2], **Robert J. Harrison, MD, MPH**[2]

[1]Division of Occupational and Environmental Medicine, University of California San Francisco, San Francisco, CA, USA

[2]California Department of Public Health, Occupational Health Branch, Richmond, CA, USA

[3]Division of Pulmonary, Critical Care and Sleep Medicine, University of California Los Angeles, Los Angeles, CA, USA

[4]California Pacific Medical Center, Division of Pulmonary and Critical Care Medicine, San Francisco, CA, USA

Abstract

Silicosis in workers exposed to respirable crystalline silica while fabricating engineered stone products is an emerging respiratory health issue. We describe silicosis in engineered stone workers in California and examine clinical features by the source of identification. Cases were identified passively using hospital-based patient discharge data or actively through outreach and medical testing following enforcement investigation. Outcomes were examined based on the source of case identification. We identified 18 cases diagnosed between 2006 and 2020. Cases identified passively compared to other identification methods were associated with lower percent predicted forced vital capacity (FVC) ($P \leq .01$), forced expiratory volume in 1 s (FEV1) ($P \leq .01$), and diffusing capacity of the lungs for carbon monoxide (DLCO) ($P < .01$) at the time of diagnosis and were more likely to be identified following death or lung transplant ($P = .01$). Our experience demonstrates delays in diagnosis and case identification when relying on passive surveillance methods. Enhanced public health surveillance systems can improve the early detection of occupational lung disease and inform future prevention policies.

Keywords

occupational lung disease; occupational disease surveillance; silicosis; engineered stone

Corresponding Author: Sheiphali A. Gandhi, Division of Occupational, Environmental, and Climate Medicine, University of California San Francisco, 2330 Post St, Ste 460, San Francisco, CA 94115, USA. sheiphali.gandhi@ucsf.edu.

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Introduction

Silicosis is a fibrotic and progressive occupational lung disease and is entirely preventable by reducing or eliminating exposure to respirable crystalline silica (RCS).[1] Silicosis can develop gradually over decades of prolonged exposure to silica dust or rapidly due to high levels of exposure leading to acute and accelerated silicosis.[1,2] Over the past ten years, silicosis cases and outbreaks have been reported internationally among workers cutting and finishing engineered stone (also called artificial, composite, agglomerated, or quartz conglomerate), primarily for countertop fabrication.[3–7] Engineered stone countertop fabrication is defined as work done on post-manufactured engineered stone countertops for customization and home design and entails cutting, polishing, grinding, and installing countertops.

The silica content of engineered stone is ~90%, compared to the much lower silica composition of natural marble (less than 5%) granite (10–45%).[8,9] As a result, engineered stone workers are exposed to higher levels of respiratory crystalline silica than what has been traditionally described.[10,11] These engineered stone countertops have become a ubiquitous alternative to natural stone worldwide due to their relatively low cost, custom design features, and superior ability to withstand damage, heat, and stains.

In 2016, the Occupational Safety and Health Administration (OSHA) established a new silica standard, which decreased the permissible exposure limit (PEL) to 50 μ/m^3 and included various ancillary provisions such as exposure assessment and medical testing.[12] For measured levels of silica greater than the PEL, the standard requires the employer to use engineering and work practice controls, as feasible, to reduce exposures to or below the PEL. In countertop manufacturing, commonly used controls include ventilation systems and water suppression.[11] If these controls are insufficient to meet the PEL, the OSHA RCS standard requires that workers be given appropriate personal respiratory protection by their employer. The new standard also establishes requirements for medical testing of workers exposed to silica at concentrations greater than 25 μ/m^3 for 30 or more days per year.[12] A baseline evaluation includes a history and physical examination, chest radiograph, tuberculosis test, and pulmonary function test (spirometry), followed by a similar periodic assessment every 3 years.[12] Silicosis is not a reportable disease to public health authorities on the federal or California-state level. When silicosis is identified by employer-based medical testing, there is no requirement for active reporting to the public health department.

In the United States, an estimated 100,000 workers in the stone fabrication industry may be potentially exposed to high levels of RCS.[13] Between 2010 and 2018, imports of engineered stone increased by ~800%, according to the US International Trade Commission.[14,15] In 2017 and 2018, OSHA's national database of industrial hygiene sampling documented silica overexposures in 29.1% (82/282) of personal air samples collected in industries where countertop fabrication occurs.[16] A recent analysis by the California Department of Public Health (CDPH) found that 25% of employees at inspected worksites in California had exposures over the PEL, and 51% of worksites had at least 1 employee with exposure over the PEL.[17] These overexposures are reflected in high disease prevalence in the engineered stone fabrication industry. At 1 countertop fabrication company in California, a worksite

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investigation identified a 12% prevalence of silicosis based on plain chest radiographs and spirometry.[18] However, a similar study in Texas found an even higher prevalence of 33.3% when more sensitive radiographic testing was used (chest computed tomography [CT]).[16] While these American studies are limited by a small number of workers, their findings are consistent with those in Queensland, Australia, where screening of 1053 workers identified 238 cases of silicosis (35 with the most severe type of silicosis or progressive massive fibrosis [PMF]), a 23% prevalence among those screened.[19,20]

Since 1978, the Occupational Health Branch (OHB) of CDPH has collaborated with National Institute for Occupational Safety and Health (NIOSH), occupational health programs in other states, and partners within California to promote worker safety and health through public health prevention activities. In January 2019, OHB staff identified a 37-year-old Hispanic man hospitalized in 2017 due to silicosis related to engineered stone fabrication ("sentinel case"). The young age of the patient in this case and increasing awareness of silicosis related to engineered stone in other jurisdictions prompted a robust public health follow-up, whose results have been described previously.[7]

This study aims to describe cases of silicosis due to engineered stone fabrication in California. It analyzes disease severity at the time of diagnosis based on the method of case identification by the public health department, whether through passive surveillance or active surveillance. By examining the occupational surveillance system utilized to identify these cases within California, we intend to highlight gaps and pathways for improvement.

Methods

Surveillance Data Source

The CDPH OHB conducts ongoing surveillance of work-related asthma, silicosis, and other respiratory diseases using various data sources. For silicosis surveillance, hospital discharge data were obtained by our staff and reviewed annually between 2006 and 2020 using silicosis diagnoses in any of 25 diagnosis codes (*International Classification of Diseases, Tenth Revision* [ICD-10] code J62) and patient age at admission of 50 or below. This age cutoff was selected to ascertain cases with probable occupational exposure to silica from engineered stone fabrication. We considered the identification of cases through hospital discharge records to be passive surveillance.

Following the identification of the sentinel case, the California Division of Occupational Safety and Health (Cal/OSHA) conducted a worksite inspection. In response, the company provided silicosis screening to all current employees working in stone fabrication areas at the company's 2 locations. Screening included pulmonary function testing (PFT) and chest radiography. Radiograph classification was performed by a NIOSH-certified B Reader physician, according to the International Labour Organization (ILO) system for pneumoconiosis.[21] Following medical evaluation by community occupational medicine physicians, we collected data on those diagnosed with silicosis related to engineered stone fabrication. Additionally, as a result of outreach activities (publications and educational programs), other cases were reported to our staff by medical providers or workers' compensation attorneys. We considered the identification of cases through employer-

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initiated medical testing or outreach-prompted reporting to the public health department to be active surveillance. Two cases identified through hospital discharge records and contemporaneous outreach-prompted reporting were classified as passive surveillance.

Case Identification and Data Abstraction

After identifying a suspected case, medical records were obtained by staff and reviewed by staff epidemiologists and physicians to confirm the diagnosis. If available, biopsy slides were reviewed by occupational pulmonary pathology experts. Confirmation of engineered stone-related silicosis was based on criteria consistent with those of NIOSH, including an occupational history indicating a high likelihood of exposure to respirable silica dust and radiographic evidence of fibrotic lung disease in a pattern supportive of this diagnosis.[22] Cases were included if there was confirmation of engineered stone product fabrication as part of their occupational history.

We abstracted the following information for each case from medical records: demographics, medical history, occupational and social history, smoking history, PFT, radiology, and clinical outcomes. If needed, we contacted affected individuals and next of kin for further occupational and social history to supplement the clinical records. The case outcome was categorized as either (1) alive without lung transplant or (2) deceased or post-lung transplant.

PFT records comprised spirometry, lung volume measurements, and diffusing capacity of the lungs for carbon monoxide (DLCO). Definitions of measurements and patterns can be found in Text Box 1. Global Lung Function Initiative (GLI) reference values were used to calculate the lower limit of normal (LLN) values for parameters from spirometry, lung volume testing, and DLCO.[23] Using spirometry and lung volumes, obstruction, restriction, and mixed obstructive/restrictive pattern were defined per the American Thoracic Society/ European Respiratory Society (ATS/ERS), with severity determined by the percent predicted FEV1.[24] We defined an abnormal DLCO as less than the LLN, with severity based upon recommendations by the ATS/ERS Task Force (mild, moderate, and severe).[24] Function interpretation was performed using spirometry and lung volume testing based upon the ATS/ERS Task Force criteria.[24]

Data Analysis

We used R (R Foundation for statistical computing) for all analyses. We analyzed PFT values (FVC, FEV1, TLC, and DLCO) as percent predicted based upon GLI-predicted values.[23] We examined associations between active and passive surveillance and FVC, FEV1, and DLCO at the time of diagnosis using Welch’s t-test. We used Fisher’s exact test to examine the difference between the type of surveillance and the case outcome at the time of case identification.

Results

We identified 18 cases of silicosis associated with engineered stone diagnosed between 2006 and 2020 in California. Characteristics are described in Table 1. The median age at diagnosis was 40 years (interquartile range [IQR] = 36–49], and the median length of

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occupational exposure was 14.5 years (IQR = 10.25–16.75). All cases were male; 16 of 18 individuals (89%) were Latino, and 2 were White (11%). Four (22%) were current or ever smokers with a mean of 7 pack-years (standard deviation [SD] = 6 pack-years). Active surveillance identified 11 cases (68%) from either employer medical testing following workplace enforcement investigation (44%, $n = 8$) or provider reporting (17%, $n = 3$). Passive surveillance identified 7 cases from hospital discharge data (39%). At the time of case identification, 12 individuals (67%) were alive, with only 1 individual on supplemental oxygen. Two cases had undergone lung transplantation.

Seventeen cases had PFT results at the time of diagnosis, summarized in Table 2. PFTs demonstrated 6% with obstruction ($n = 1$), 47% with restriction ($n = 8$), 24% with mixed obstructive/restrictive pattern ($n = 4$), and 24% with normal testing ($n = 4$). Diffusion capacity was normal in 41% ($n = 7$) but mildly impaired in 18% ($n = 3$), moderately impaired in 18% ($n = 3$), and severely impaired in 24% ($n = 4$).

Cases identified by active surveillance had higher percent predicted lung function parameters at the time of diagnosis than those identified by passive surveillance, as follows: percent predicted FVC (78 ± 17% vs 48 ± 11; $P \leq .01$), FEV1 (77 ± 20% vs 36 ± 16%; $P \leq .01$), and DLCO (90 ± 26% vs 44 ± 16%; $P < .01$) (Table 3). Figure 1 demonstrates the pattern of PFT and diffusion abnormality by the source of case identification, indicating more severe abnormalities among those cases identified through passive surveillance. Among cases identified through active surveillance, 9 (82%) were alive without a lung transplant, and only 2 (18%) were deceased or had undergone a lung transplant. Conversely, those identified with passive surveillance were more often deceased or transplanted ($n = 6$; 86%), with only 1 individual still living ($P = .01$).

Discussion

We present surveillance data regarding a large single-state case series of silicosis associated with engineered stone. Cases had high severity attributable to silica exposure and high healthcare utilization, including lung transplantation. Our data show significant differences between the groups identified by active versus passive surveillance in both severity of illness at the time of diagnosis and case outcome. Those identified through active public health surveillance were more likely to be identified with milder disease. In contrast, those identified through passive surveillance were more likely to have severe disease or have died or undergone a lung transplant.

Early identification of silicosis cases can allow the removal of workers from further occupational exposure and prompt implementation of additional workplace protections for co-workers. This analysis clearly demonstrates a critical delay in public health case identification when relying solely on hospital discharge data and the current informal provider referral system for public health surveillance. The majority of cases identified through discharge data were found to have severely or very severely impaired pulmonary function at the time of diagnosis and were more likely to be deceased or have undergone lung transplants at the time of public health case identification.

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Our findings are limited by our small sample size, which is unsurprising considering the previously discussed gaps in our silicosis surveillance system. Our data set was limited to those identified within California; therefore, these findings are not fully generalizable to the United States or international settings. Despite this, the challenges faced by all public health systems are comparable in their overreliance on surveillance of highly symptomatic diseases and appropriate diagnosis by medical providers.

Early identification of silicosis in exposed workers is critical to detecting disease in a pre-clinical stage. Numerous case series have found that cases identified among engineered stone workers tend to be young with minimal years of exposure.[3–7] However, many of these case identification programs rely on symptomatic disease, with many workers presenting either with the most severe forms of the disease, such as PMF, or at the point of end-stage lung disease, lung transplantation, or death.[3–7] Though there are few longitudinal follow-up studies on this emerging occupational respiratory hazard, there is evidence of accelerated loss of lung function. Studies from other industries demonstrate that risk of progression has been associated with cumulative silica dust exposure, younger age, lower lung function, and larger size and extent of opacities on initial diagnostic chest radiology.[26–30] In workers exposed to coal mine dust who transferred to less dusty jobs due to chest radiograph with pneumoconiosis, those who did not progress had lower severity at the time of diagnosis, suggesting that intervening earlier in the disease process is associated with better outcomes.[31] As cumulative dust exposure may predict the progression of silicosis, removal from exposure is crucial for secondary prevention efforts to reduce disease severity. Equally important is identifying workplace hazards at the affected worker's workplace that can be mitigated to prevent other workers from being exposed and developing silicosis.

We suspect that a substantial portion of silicosis related to engineered stone fabrication does not come to the attention of public health authorities. In Figure 2, we propose a schematic illustrating the cascade of silicosis surveillance among engineered stone fabricators. Here we propose diminishing case identification based on source compared to the true estimated prevalence among exposed workers. In our case series, each of the passively identified cases and many actively identified cases serve as "sentinels" for their workplaces, suggesting the burden of disease is much greater than this series alone implies. Enhanced active public health surveillance systems with worksite medical testing can improve the early detection of occupational lung disease and provide data for prevention policies going forward. If employers followed mandated medical testing protocols (based upon workplace-regulated exposure limits of respirable silica), pre-symptomatic workers could be identified (as demonstrated in our study), thus allowing for earlier diagnosis and public health intervention. In a recent study, we found that 36% of engineered stone fabrication workshops investigated by Cal/OSHA were cited for failure to perform medical testing.[17] Another consideration is to lower the threshold for testing due to the toxicity of engineered stone fabrication with mandated medical testing for all workers, irrespective of air sampling.

Unfortunately, our current systems in California rely primarily on passive surveillance and death records (right side of Figure 2). By the time cases come to public health attention, workplace silica dust exposures have likely been ongoing for many years and have affected many more workers. By this point, the disease stage has likely progressed beyond what may

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benefit from early intervention. If employers consistently performed required medical testing and public health surveillance that were expanded to utilize all statewide electronic medical records, including outpatient records, additional pre-symptomatic and early symptomatic cases could be identified. For example, natural language processing and rapid collection of inpatient and outpatient medical records through state- or nationwide databases (eg, Reportable Conditions Knowledge Management System [RCKMS]) is a promising tool to allow public health officials to be at the forefront of case identification for rare but highly morbid diseases as well as to determine the incidence of more common diseases.[32,33]

Another critical source for public health surveillance of pneumoconiosis such as silicosis is the NIOSH B Reader Program. B Readers identify cases of pneumoconiosis based on radiographic findings, including in those who are pre-symptomatic. A chest radiograph that includes classification by a B Reader is a required component of medical testing under the federal OSHA and Cal/OSHA silica standards. However, existing regulations do not require reporting of B Reader results to public health authorities. In comparison, national industrywide chest radiographic surveillance by NIOSH is mandated under the Federal Coal Mine Health and Safety Act of 1969. This surveillance program has demonstrated an increase in the identification of severe pneumoconiosis and PMF in Appalachian coal miners over the last decade.[34] If a similar system were implemented for silicosis, clusters of cases could be identified, prompting further public health investigation and intervention.

As noted in Figure 2, many gaps within surveillance systems are denoted as “inappropriate exit(s).” These issues, such as misdiagnosis and poor medical testing compliance, could be improved with increased physician, employer, and workers’ educational programs to engage all stakeholders in overall worker respiratory health. An important inappropriate “exit” to note is early exit despite the risk of progression in the face of initial normal testing. Due to the severity of exposure in engineered stone workers, severe disease progression can occur even after removal from exposure,[35] so longitudinal follow-up and repeat testing are needed even if initial testing is normal. In addition, employer-provided medical testing is mandated only for current workers. Former workers, who continue to be at risk of disease development due to earlier exposure, are omitted.

A direct result of medical testing is “secondary prevention” or identifying workers at early stages of disease to mitigate disease progression or provide treatment. In addition, as demonstrated in California’s surveillance program, identifying a “sentinel” case through disease surveillance can motivate “primary prevention,” where steps can be taken to prevent further workers from being exposed to hazardous work conditions. This primary prevention typically occurs due to public health or enforcement intervention following sentinel case identification. However, as noted in Figure 2, another common source of wrong exit from the surveillance system is the lack of reporting of the cases to public health departments and occupational safety and health departments (eg, OSHA). Silicosis is not consistently reportable throughout the United States, with few states (eg, New Jersey and Michigan) mandatorily requiring hospitals and clinicians to report directly to the public health department.[36] Making silicosis a mandatory reportable disease to the local and state-level health departments would improve disease incidence and prevalence estimates, prompt worksite investigations, and allow for primary prevention.

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As noted previously, silicosis outbreaks due to engineered stone fabrication have been reported internationally since 2010.[37] Public health responses to these cases have been varied, as demonstrated within the United States. Australia's response to reports of accelerated silicosis in young workers exposed to engineered stone has been exemplary. In 2019, they formed the National Dust Disease Taskforce and tightened the RCS standard to 0.05 mg/m^3.[38] In the Australian state of Queensland, a safety report was issued in 2018, after which they conducted a statewide audit of 140 fabrication worksites. Through the collaboration of Queensland public health officials and government-owned workers' compensation insurance (WorkCover Queensland), a program was developed for health screening of all exposed workers and compensation of wages if workers were found to have work-related lung disease.[19,39] Through this program, 1053 workers have been screened, identifying 238 cases of silicosis (35 with PMF), indicating a 23% prevalence of silicosis of those screened.[19,20] This collaboration between workers' compensation insurance and employer health screening is innovative and highlights the need for greater collaboration and partnership between key stakeholders to produce an overall beneficial outcome for workers with silicosis.

Intensive legal strides have been made internationally to combat silica exposure from engineered stone. The owner of a major Spanish engineered stone manufacturer was indicted this year. In a plea deal, he admitted to negligence of warning affected workers who developed silicosis. For this, he received a prison sentence and paid heavy fines.[40] Soon after, a new low-silica stone product was announced by the company.[41] California has a no-fault workers' compensation law enacted by the state legislature. The intention of the system is to provide prompt, automatic benefits to workers injured on the job. The system also precludes personal injury lawsuits against employers by workers if workers' compensation insurance is provided., Nonetheless, third-party lawsuits are permitted; in California, 17 lawsuits have been filed against dozens of engineered stone countertop manufacturers by stone fabricators or survivors of those who have died. Court cases are currently pending.[42] Increased legal pressure on engineered stone manufacturers could result in innovations by industry for safer alternatives and increased oversight on engineered stone fabrication.

In order to visualize the importance of controls in workplace exposures, NIOSH developed the "Hierarchy of Controls" (seen in Figure 3) that depicts an inverted triangle to determine how to implement effective hazard control solutions. The triangle is split into 5 sections, elimination, substitution, engineering controls, administrative controls, and personal protective equipment, in descending order of effectiveness.[43]

The most effective approach (as noted in Figure 3) to protect workers is to eliminate the toxic product altogether. For example, efforts have been made by the Australian federal government in recent months to consider a ban on artificial stone in the country through a unanimous recommendation of all state work health and safety ministers.[44] Furthermore, Australian construction unions have plans to ban the product by 2024 if the federal government fails to do so.[45] This proposed ban cites the inadequacy of engineering controls and personal protective equipment to protect engineered stone fabricators. The government's proactive approach to consider banning high-risk products like engineered stone sets a precedent for other countries to prioritize the health and well-being of stone workers.

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In the realm of substitution of products, returning to natural stone products (eg, marble and granite) or usage of non-stone-based products (eg, wood, tile) does not eliminate all exposures to workers but substitutes the most toxic products by lesser ones ("substitution" in Figure 3). Engineered stone manufacturers have been advertising low silica engineered stone containing less than 40% silica,[46–48] but the safety of these products is still unclear.

Engineering controls (see Figure 3) play a crucial role in improving the safety of workers involved in engineered stone fabrication. Implementing engineering controls is essential, given the high silica content and associated health risks. Water suppression can reduce crystalline silica dust exposure by 10-fold,[11] minimizing respirable dust generation by wetting down surfaces and capturing airborne particles directly at the equipment. Unfortunately, reducing exposure below the PEL is often insufficient without local exhaust ventilation and appropriate personal protective equipment.[11,49] In 2019 and 2020, states in Australia banned dry cutting in hopes of mandating engineering controls for engineered stone.[50–52]

Though elimination or substitution is preferred in the hierarchy of controls, in the asbestos abatement industry, administrative controls in the form of asbestos certification for mitigation play a role in attempting to create safe and effective management of asbestos-containing materials. This certification process involves training and assessment to equip professionals with the knowledge and skills to identify, evaluate, and handle asbestos for abatement. The goal is that asbestos mitigation is carried out by trained experts who prioritize safety and adhere to proper procedures, ultimately minimizing the risk of asbestos exposure and related health hazards.[53,54] A consideration could be made for an analogous process within the engineered stone countertop industry with increased oversight of all engineered stone countertop fabrication in registered shops with regular monitoring to ensure compliance. The goal would be for increased transparency in the industry's safety through reporting and increased monitoring. Lastly, though personal protective equipment is often cited by clinicians as an important measure to reduce risk, it is considered to be of the lowest effectiveness in the hierarchy of controls. Although respiratory protection can reduce silica exposures if worn correctly and consistently, respirators require significant and ongoing effort on the part of workers and employers. Data from recent Cal/OSHA inspections indicate that poor compliance with respiratory protection regulations is widespread in the engineered stone fabrication industry.[17,55] Furthermore, the high silica exposures documented in some countertop fabrication workplaces suggest that more commonly used disposable and half-face respirators may not be sufficiently protective.[17]

The importance of case identification and exposure mitigation is paramount. As noted previously, there are an estimated 100,000 workers in the stone fabrication industry in the United States.[13] If the prevalence of silicosis in this industry is on the order of 23% to 33% as seen in Australia and Texas, the number of affected workers could exceed 20,000. A national epidemic of this scale would represent one of the largest occupational respiratory disasters in US history. Our experience provides convincing evidence in favor of more robust public health occupational disease surveillance and improved medical testing of silica-exposed workers. The differences in disease severity and outcomes between cases

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identified through active and passive surveillance are particularly striking and highlight the impact of delays in identification. Further work is needed to make highly morbid occupational diseases such as silicosis reportable to public health departments and bolster pre-symptomatic medical testing systems to reduce the burden of silicosis and protect vulnerable workers.

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Biographies

Sheiphali A. Gandhi, MD is an Assistant Professor at the University of California San Francisco in the Division of Occupational, Environmental, and Climate Medicine and is a dual-boarded pulmonologist and occupational medicine physician, specializing in occupational and environmental respiratory disease. She is Associate Director of the San Francisco Veteran's Association Post-Deployment Cardiopulmonary Evaluation Network, assessing veterans with military exposures in Southwest Asia. Her research concentrates on the epidemiology of interstitial lung disease including pneumoconiosis and the occupational contributions to health disparities.

Amy Heinzerling, MD, MPH is a Medical Officer in the Occupational Health Branch at the California Department of Public Health and an Assistant Clinical Professor in the Division of Occupational, Environmental, and Climate Medicine at the University of California San Francisco.

Jennifer Flattery, MPH is a Research Scientist Supervisor in the Occupational Health Branch at the California Department of Public Health.

Jane C. Fazio, MD is a Clinical Instructor at the University of California Los Angeles (UCLA) in the Division of Pulmonary, Critical Care, and Sleep Medicine and a PhD Candidate in the UCLA Fielding School of Public Health.

Asim Alam, MD, PhD is a Clinical Fellow in the Division of Pulmonary and Critical Care Medicine at the California Pacific Medical Center in San Francisco, California.

Kristin J. Cummings, MD, MPH is Chief of the Occupational Health Branch at the California Department of Public Health.

Dr. Robert J. Harrison, MD, MPH is Chief of the Occupational Health Surveillance and Evaluation Program in the Occupational Health Branch at the California Department of Public Health (CDPH) and a Senior Physician Diplomate in the Division of Occupational and Environmental Medicine at the University of California San Francisco.

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References

1. Leung CC, Yu ITS and Chen W. Silicosis. Lancet 2012; 379: 2008–2018. [PubMed: 22534002]
2. Barnes H, Goh NSL, Leong TL, et al. Silica-associated lung disease: an old-world exposure in modern industries. Respirology 2019; 24: 1165–1175. [PubMed: 31517432]
3. Kramer MR, Blanc PD, Fireman E, et al. Artificial stone silicosis: disease resurgence among artificial stone workers. CHEST 2012; 142: 419–424. [PubMed: 22383661]
4. Hoy RF, Baird T, Hammerschlag G, et al. Artificial stone-associated silicosis: a rapidly emerging occupational lung disease. Occup Environ Med 2018; 75: 3–5. [PubMed: 28882991]
5. Leso V, Fontana L, Romano R, et al. Artificial stone associated silicosis: a systematic review. Int J Environ Res Public Health 2019; 16: 568. [PubMed: 30781462]
6. Martínez González C, Prieto González A, García Alfonso L, et al. Silicosis in artificial quartz conglomerate workers. Archivos de Bronconeumología (English Edition). 2019;55:459–464.
7. Rose C. Severe silicosis in engineered stone fabrication workers — California, Colorado, Texas, and Washington, 2017–2019. MMWR Morb Mortal Wkly Rep 2019; 68: 813–818. [PubMed: 31557149]
8. Occupational Safety and Health Administration, National Institute of Occupational Safety and Health - Center for Disease Control. HAZARD ALERT | Worker Exposure to Silica during Countertop Manufacturing, Finishing and Installation | Occupational Safety and Health Administration, https://www.osha.gov/dts/hazardalerts/silica_hazard_alert.html (2015, accessed 18 October 2019).
9. Lim W. Crystalline Silica. Health and Safety: University of Melbourne, https://safety.unimelb.edu.au/safety-topics/silica (2022, accessed 18 April 2023).
10. Phillips ML, Johnson DL and Johnson AC. Determinants of respirable silica exposure in stone countertop fabrication: a preliminary study. J Occup Environ Hyg 2013; 10: 368–373. [PubMed: 23668829]
11. Cooper JH, Johnson DL and Phillips ML. Respirable silica dust suppression during artificial stone countertop cutting. Ann Occup Hyg 2015; 59: 122–126. [PubMed: 25326187]
12. Occupational Safety and Health Administration (OSHA), Department of Labor. Occupational exposure to respirable crystalline silica. Final rule. Fed Regist. 2016;81:16285–16890. [PubMed: 27017634]
13. U.S. Bureau of Labor Statistics. Quarterly census of employment and wages, https://www.bls.gov/cew/data.htm (2021, accessed 4 January 2021).
14. United States International Trade Commission for Harmonized Tariff Schedule (HTS) code: 6810.99.0010. Agglomerated quartz slabs of the type used for countertops, https://dataweb.usitc.gov/ (2023, accessed 25 May 2023).
15. Dodd KE, Heinzerling A, Rose C, et al. Outbreak of silicosis among engineered stone countertop workers in four states. CDC, https://blogs.cdc.gov/niosh-science-blog/2019/10/29/silicosis-countertop/ (2019, accessed 25 May 2023).
16. Tustin AW, Kundu-Orwa S, Lodwick J, et al. An outbreak of work-related asthma and silicosis at a US countertop manufacturing and fabrication facility. Am J Ind Med 2022; 65: 12–19. [PubMed: 34671999]
17. Surasi K, Ballen B, Weinberg JL, et al. Elevated exposures to respirable crystalline silica among engineered stone fabrication workers in California, January 2019-February 2020. Am J Ind Med 2022; 65: 701–707. [PubMed: 35899403]
18. Heinzerling A, Cummings KJ, Flattery J, et al. Radiographic screening reveals high burden of silicosis among workers at an engineered stone countertop fabrication facility in California. Am J Respir Crit Care Med 2021; 203: 764–766. [PubMed: 33207123]
19. Workplace Health and Safety Queensland. 1000+ stonemasons now screened for silicosis in Queensland, https://www.worksafe.qld.gov.au/news-and-events/newsletters/esafe-newsletters/esafe-editions/esafe/february-2020/1000-stonemasons-now-screened-for-silicosis-in-queensland (2020, accessed 30 March 2023).

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

20. Hoy RF and Sim MR. Correspondence on 'demographic, exposure and clinical characteristics in a multinational registry of engineered stone workers with silicosis' by Hua et alet al. Occup Environ Med 2022; 79: 647–648.

21. International Labour Office. Guidelines for the Use of the ILO International Classification of Radiographs of Pneumoconioses. Revised edition 2011. Geneva, Switzerland: International Labour Office, 2011.

22. NIOSH. NIOSH hazard review: health effects of occupational exposure to respirable crystalline silica. US Department of Health and Human Services; 2002. doi:10.26616/NIOSHPUB2002129

23. Cooper BG, Stocks J, Hall GL, et al. The Global Lung Function Initiative (GLI) network: bringing the world's respiratory reference values together. Breathe 2017; 13: e56–e64. [PubMed: 28955406]

24. Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. Eur Respir J 2005; 26: 948–968. [PubMed: 16264058]

25. Moore VC. Spirometry: step by step. Breathe 2012; 8: 232–240.

26. Mohebbi I and Zubeyri T. Radiological progression and mortality among silica flour packers: a longitudinal study. Inhal Toxicol 2007; 19: 1011–1017. [PubMed: 17917915]

27. Akgun M, Araz O, Ucar EY, et al. Silicosis appears inevitable among former denim sandblasters: a 4-year follow-up study. Chest 2015; 148: 647–654. [PubMed: 25654743]

28. Karataş M, Gündüzöz M, Büyükş ekerci M, et al. Radiological progression and lung function decrements among silica-exposed ceramic workers: a longitudinal study. Inhalation Toxicol 2019; 31: 119–124.

29. Ng TP, Chan SL and Lam KP. Radiological progression and lung function in silicosis: a ten year follow up study. Br Med J (Clin Res Ed) 1987; 295: 164–168.

30. Lee HS. Radiological progression and its predictive risk factors in silicosis. Occup Environ Med 2001; 58: 467–471. [PubMed: 11404452]

31. Hall NB, Blackley DJ, Halldin CN, et al. Pneumoconiosis progression patterns in US coal miner participants of a job transfer programme designed to prevent progression of disease. Occup Environ Med 2020; 77: 402–406. [PubMed: 32169972]

32. Reportable Conditions Knowledge Management System. Communications, https://www.rckms.org/ (2022, accessed 23 May 2022).

33. Eilbeck KL, Lipstein J, McGarvey S, et al. Evaluation of need for ontologies to manage domain content for the Reportable Conditions Knowledge Management System. AMIA Annu Symp Proc 2014; 2014: 496–505. [PubMed: 25954354]

34. Blackley DJ, Halldin CN and Laney AS. Resurgence of a debilitating and entirely preventable respiratory disease among working coal miners. Am J Respir Crit Care Med 2014; 190: 708–709. [PubMed: 25221884]

35. León-Jiménez A, Hidalgo-Molina A, Conde-Sánchez MÁ, et al. Artificial stone silicosis: rapid progression following exposure cessation. CHEST 2020; 158: 1060–1068. [PubMed: 32563682]

36. Schleiff PL. Surveillance for silicosis—Michigan and New Jersey, 2003–2011. MMWR Morb Mortal Wkly Rep 2016; 63: 73–78. [PubMed: 27736836]

37. García Vadillo C, Gómez JS and Morillo JR. Silicosis in quartz conglomerate workers. Archivos de Bronconeumología ((English Edition)). 2011; 47: 53.

38. Australian Government. National Dust Disease Taskforce. Department of Health and Aged Care, https://www1.health.gov.au/internet/main/publishing.nsf/Content/ohp-nat-dust-disease-taskforce.htm (2022, accessed 3 November 2021).

39. Queensland W. Silicosis, https://www.worksafe.qld.gov.au/claims-and-insurance/work-related-injuries/types-of-injury-or-illness/work-related-respiratory-diseases/silicosis (2020, accessed 10 December 2022).

40. Reuters. Owner of Spain's Cosentino admits negligence over silicosis in workers - documents. Reuters, https://www.reuters.com/business/owner-spains-cosentino-admits-concealing-cause-silicosis-1900-workers-2023-02-07/ (2023, accessed 18 May 2023).

41. Cosentino. Cosentino statement, https://www.cosentino.com/news/cosentino-statement/ (2023, accessed 27 May 2023).

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42. Morris J and Krisberg K. California regulators drafting emergency rule to combat deadly lung disease. Public Health Watch, http://publichealthwatch.org/2023/05/10/california-regulators-drafting-emergency-rule-to-combat-deadly-lung-disease/ (2023, accessed 18 May 2023).
43. CDC. Hierarchy of Controls. NIOSH Workplace Safety and Health Topic, https://www.cdc.gov/niosh/topics/hierarchy/default.html (2023, accessed 15 October 2019).
44. Karp P. Australia moves to fast-track ban on silica stone benchtops that cause fatal lung disease. The Guardian, https://www.theguardian.com/australia-news/2023/feb/28/australia-moves-to-ban-silica-engineered-stone-benchtops-silicosis-fatal-lung-disease (2023, accessed 30 March 2023).
45. Thompson A. 'Risking lives for fashionable finish': Unions clash with business on benchtop ban. The Sydney Morning Herald, https://www.smh.com.au/politics/federal/fashionable-finish-unions-clash-with-business-over-total-benchtop-ban-20230418-p5d18n.html (2023, accessed 25 May 2023).
46. Cosentino. Hybriq Pro, https://www.cosentino.com/silestone/hybriq-technology-pro/ (2023, accessed 27 May 2023).
47. Smartstone. Ibrido low silica surfaces set a new industry standard, https://www.smartstone.com.au/low-silica-surfaces-ibrido-industry-standard-safety/ (2022, accessed 27 May 2023).
48. Home Beautiful. A ban on engineered stone benchtops: what you need to know, https://www.homebeautiful.com.au/engineered-benchtops-stone-silicosis (2023, accessed 27 May 2023).
49. Johnson DL, Phillips ML, Qi C, et al. Experimental evaluation of respirable dust and crystalline silica controls during simulated performance of stone countertop fabrication tasks with powered hand tools. Ann Work Expo Health 2017; 61: 711–723. [PubMed: 28927166]
50. Safety Solutions. Silicosis danger prompts ban on dry cutting stone in Qld, http://safetysolutions.net.au/content/nsca-foundation/news/silicosis-danger-prompts-ban-on-dry-cutting-stone-in-qld-738804638 (2018, accessed 22 October 2019).
51. Australian Institute of Health & Safety. Victoria bans uncontrolled dry cutting of engineered stone, https://www.aihs.org.au/news-and-publications/news/victoria-bans-uncontrolled-dry-cutting-engineered-stone (2019, accessed 27 May 2023).
52. Patty A. NSW to ban dry cutting of stone products to combat deadly silicosis. The Sydney Morning Herald, https://www.smh.com.au/business/workplace/nsw-to-ban-dry-cutting-of-stone-products-to-combat-deadly-silicosis-20200220-p542qr.html (2020, accessed 27 May 2023).
53. National Institute of Occupational Safety and Health. Asbestos, https://www.cdc.gov/niosh/topics/asbestos/default.html (2023, accessed 26 May 2023).
54. US Department of Labor. Asbestos - Overview. Occupational Safety and Health Administration, https://www.osha.gov/asbestos (2014, accessed 26 May 2023).
55. Spiegel A, Cummings KJ, Flattery J, et al. Self-reported silica exposures and workplace protections among engineered stone fabrication workers in California. Am J Ind Med 2022; 65: 1022–1024. [PubMed: 36214615]

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Text Box 1.

An Explanation for Those Unfamiliar with PFT

Spirometry refers to the basic lung (**pulmonary**) function tests that measure air that is exhaled and inhaled.[25]

Spirometric parameters:

FEV1: The patient takes a deep breath in as large as possible, blows air out as hard and fast as possible, and keeps going until no air is left. The measurement is the volume of air produced in the first second of exhalation.[24]

Forced Vital Capacity (FVC): The maximum volume of air that can be exhaled when blowing out as fast as possible.[24]

Diffusing capacity of the lungs for carbon monoxide (DLCO) is a measurement to assess the lungs' ability to transfer gas to the bloodstream. Carbon monoxide is used for this test, not because of its toxicity but because its tendency to bind with hemoglobin in red blood cells is more than 200 times that of oxygen.[24] The DLCO measurement is compared to a normal value similar to the spirometry and can be decreased mildly, moderately, or severely. From this the total lung capacity (TLC) can be determined which is the volume in the lungs at maximal inflation.

Lung volume measurement includes measurements that refer to the volume of air in the lungs at different phases of the respiratory cycle. It is not a forced measurement (unlike spirometry) and measures the functional residual capacity (FRC) which is the volume in the lungs when the muscles of respiration are relaxed.

In order to understand the health implications of the results of the lung function tests conducted on engineered stone fabrication workers in California, the authors compared those results to the **LLN** and the **upper limit of normal (ULN)** calculated by the GLI. GLI makes these calculations using data from lung function testing around the world.[23,24]

PFT Patterns

- **Obstruction** is an impediment to exhaling air. Breathing is obstructed when a patient's ability to exhale is considerably less than expected.[4] It is defined by the ratio of FEV1/FVC being less than the LLN.[24]
- **Restriction** is a reduced ability of the lungs to expand during inhalation, thus decreasing the amount of air the person can inhale[4]. It is suggested by the FVC being less than the LLN and confirmed by low TLC.[24]
- **Mixed pattern** occurs when there is both an impediment to exhaling air and a reduced ability of the lungs to expand. It is defined by (1) FEV1/FVC < LLN and (2) FVC < LLN.[24]

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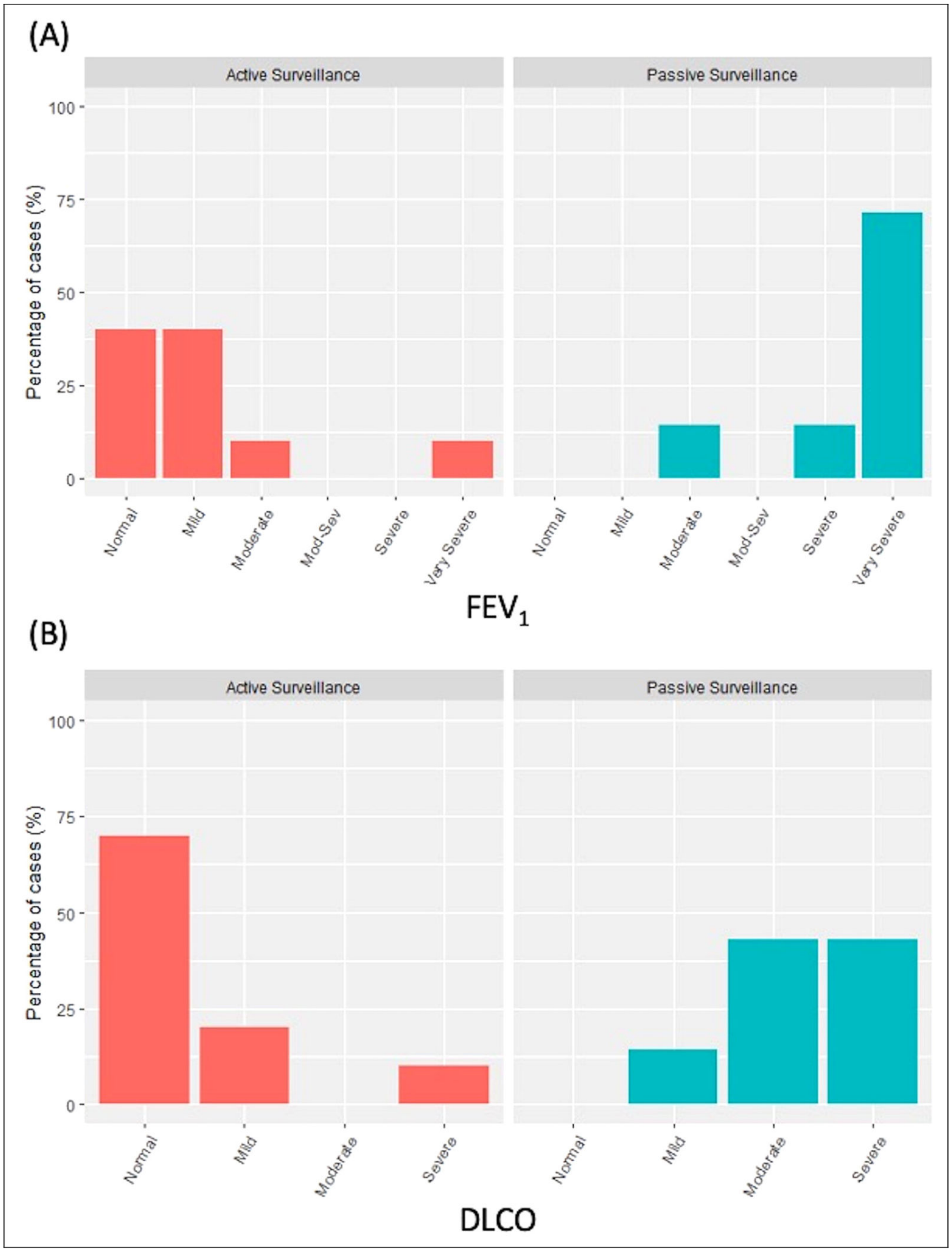

Figure 1.

Bar graph of the percentage of pulmonary function values at the time of case identification based upon active or passive surveillance as defined by the ATS/ERS taskforce criteria. (a) Forced expiratory volume in 1 s (FEV1) and (b) single breath carbon monoxide diffusion capacity (DVCO).

Abbreviations: ATS/ERS, American Thoracic Society/European Respiratory Society; mod-sev, moderate-severe.

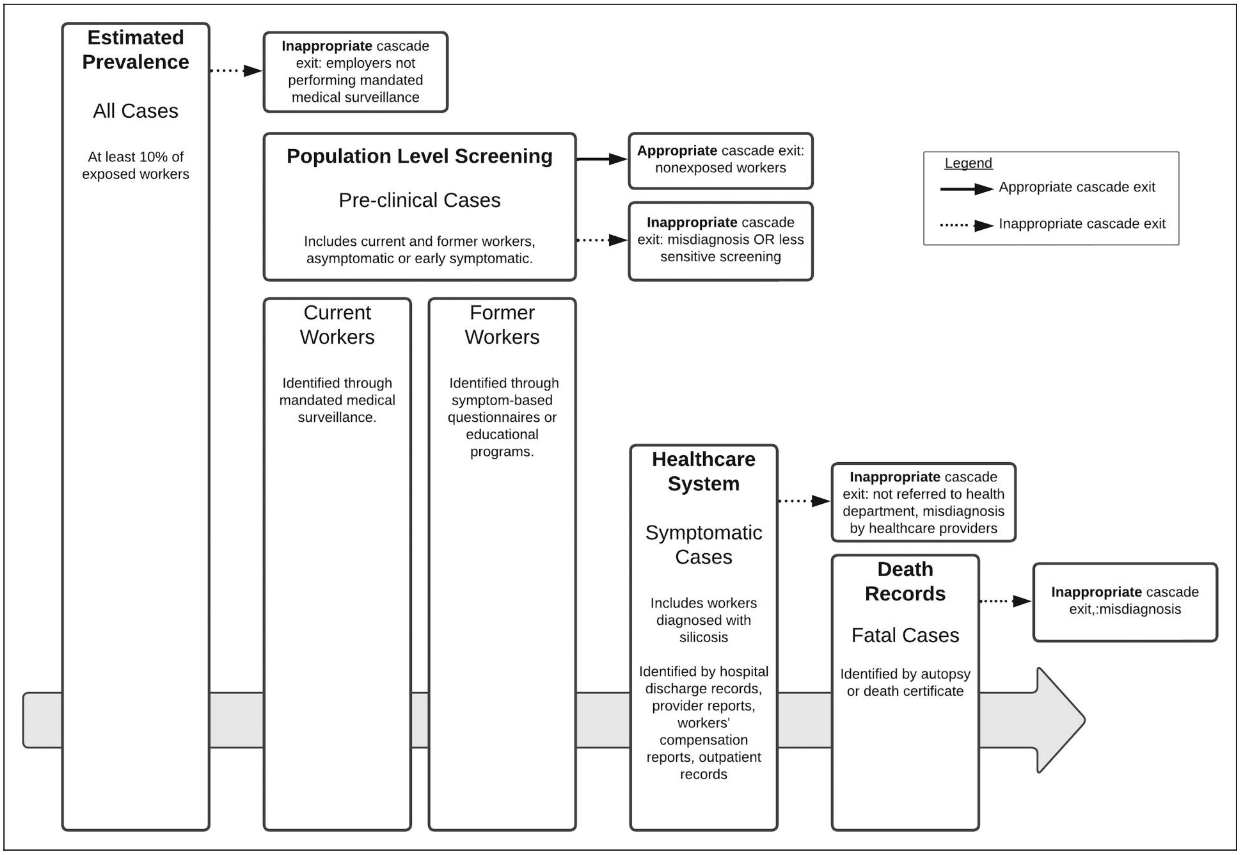

Figure 2.

Population-based cascade of surveillance for silicosis associated with engineered stone fabrication with the size of each aspect of surveillance representing diminishing case identification.

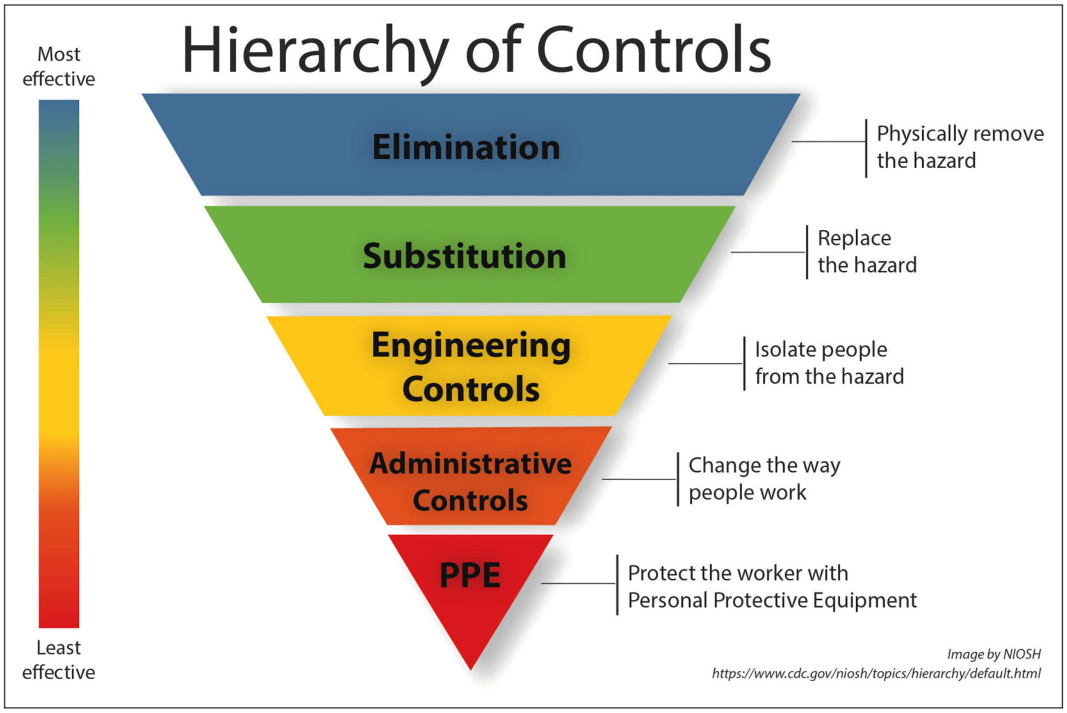

Figure 3.
The hierarchy of controls was developed by the National Institute of Occupational Safety and Health.

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Table 1.

Demographic and Clinical Characteristics of 18 Workers with Engineered Stone Silicosis.

Male sex	18 (100%)
Age, years	
Median	40
IQR	36–49
Years of exposure to engineered stone dust, years	
Median	14.5
IQR	10.25–16.75
Race/ethnicity, *n* (%)	
Latino	16 (89%)
White, not Hispanic	2 (11%)
Ever smoker, *n* (%)	4 (22%)
Pack-years	7 ± 6
Source of case identification, *n* (%)	
California hospital discharge data	7 (39%)
Cal/OSHA worksite investigations	8 (44%)
Provider reporting	3 (17%)
Clinical status at time of case identification, *n* (%)	
Alive, no oxygen	10 (56%)
Alive, on oxygen	1 (6%)
Deceased	7 (39%)
Lung transplant	2 (11%)

Abbreviations: Cal/OSHA, California Division of Occupational Safety and Health; IQR, interquartile range.

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Table 2.

Lung Function at the Time of Diagnosis.

Pulmonary function pattern (*n*=17)	***n* (%)**
Normal	4 (24%)
Obstruction	1 (6%)
Restriction	8 (47%)
Mixed	4 (24%)
FEV1 severity in subjects with abnormal PFT pattern (*n* = 13)	*n* (%)
Mild (>70% and <LLN)	4 (24%)
Moderate (60–69%)	2 (12%)
Moderately severe (50–59%)	-
Severe (35–49%)	1 (6%)
Very severe (<35%)	6 (43%)
Diffusion capacity pattern (*n* = 17)	*n* (%)
Normal	7 (41%)
Mild	3 (18%)
Moderate	3 (18%)
Severe	4 (24%)

Abbreviations: PFT, pulmonary function test; diffusion capacity, single-breath carbon monoxide diffusion capacity, LLN, lower limit of normal.

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Table 3.

Mean Percent Predicted FVC, FEV1, and DLCO Based on the Type of Surveillance Used for Case Identification.

	Active surveillance (*n* = 11)	**Passive surveillance (*n* = 7)**	***P***
	Mean ± SD (%)	**Mean ± SD (%)**	
FVC percent predicted	78 ± 17	48 ± 11[a]	<.01
FEV1 percent predicted	77 ± 20	36 ± 16[a]	<.01
DLCO percent predicted	90 ± 26	44 ± 16[a]	<.01
	n (%)	*n* (%)	
Alive, no lung transplant	9 (82%)	1 (14%)	.01
Deceased or lung transplant	2 (18%)	6 (86%)	

Abbreviations: DLCO, diffusing capacity of the lungs for carbon monoxide; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacit.

[a] *n* = 6.