



## Silicosis in Denim Sandblasters

Nur Dilek Bakan, MD; Gülcihan Özkan, MD; Güngör Çamsarı, MD; Aygün Gür, MD; Mehmet Bayram, MD; Barış Açıkmeşe, MD; and Erdoğan Çetinkaya, MD

**Background:** During the past 2 decades, silica sand has been used widely in sandblasting denim in Turkey, which has resulted in an epidemic of silicosis. This study was conducted to summarize the clinical outcomes of formerly healthy young people who became disabled or died because of working in the textile industry.

**Methods:** The medical records of patients with silicosis due to denim sandblasting who were seen at our institution between 2001 and 2009 were reviewed. Follow-up data were assessed. Compensation and vital status of patients were determined, and survival analysis was performed.

**Results:** Thirty-two male patients diagnosed with silicosis due to denim sandblasting over an 8-year period were identified. Mean age was 31.5 years. They worked as denim sandblasters for a mean 66.4 h/wk for a median 28.5 months. Their mean cumulative exposure time to silica sand was 12,957 h. The median follow-up period was 29 months (range 3-101 months). The median latency period (time elapsed between initial exposure and diagnosis) was 5.5 years (range 2-14 years). Six of the followed patients (19%) died of progressive massive fibrosis. Nine of the patients (28%) were compensated because of silicosis. Just two patients with silicosis received compensation before they died. The mean survival rate was 78 months. The estimated 5-year survival rate was 69% for denim sandblasters with silicosis.

**Conclusions:** Silicosis in young individuals after exposure in the textile sector suggests a lack of awareness of the hazards of silica outside of the traditional occupations associated with silicosis. Death from silicosis in young people suggests overexposure and unsafe working conditions as a result of a lack of control. *CHEST 2011; 140(5):1300-1304*

**Abbreviations:** DLCO = diffusing capacity of the lung for carbon monoxide

Although it is one of the oldest occupational diseases, silicosis is still reported in both the developed and developing world. It is a disabling and potentially fatal lung disease for which there is no cure. However, it is preventable by controlling exposure to respirable crystalline silica.<sup>1,2</sup> Silica exposure and silicosis have been associated with a wide variety of industries. Abrasive blasting involves forcefully

projecting a stream of abrasive particles onto a surface with compressed air, often abrading glass or metal.<sup>3</sup> Because silica sand is commonly used in this process, workers who undertake this occupation are often called sandblasters. During the past 2 decades, sandblasting of denim has been performed in Turkey to give the material a localized abrasion effect, which is a separate procedure from stonewashing or chemical bleaching. Sand is blasted onto the material at a high speed to give an old, worn, and/or used look. The force of the abrasion rubs off the indigo-dyed fibers.

The first diagnosis of silicosis caused by denim sandblasting was reported 8 years ago. It has been 4 years since the first four cases were presented at the annual European Respiratory Society Congress by two different Turkish teams.<sup>4,5</sup> The increased popularity of distressed jeans has resulted in additional cases of silicosis and deaths due to this new application of sandblasting.<sup>6,7</sup> This study was conducted to summarize

Manuscript received July 21, 2010; revision accepted April 11, 2011.

**Affiliations:** From the Yedikule Teaching Hospital for Chest Diseases and Thoracic Surgery, Chest Diseases, Istanbul, Turkey.

**Funding/Support:** The authors have reported to *CHEST* that no funding was received for this study.

**Correspondence to:** Nur Dilek Bakan, MD, I. Kisim mah. Spradon Quartz sitesi Buket sok. AC1 blok D:6 Bahcesehir 34488 Istanbul, Turkey; e-mail: nurdilek29@yahoo.com

© 2011 American College of Chest Physicians. Reproduction of this article is prohibited without written permission from the American College of Chest Physicians (<http://www.chestpubs.org/site/misc/reprints.xhtml>).

DOI: 10.1378/chest.10-1856

the clinical outcomes of 32 formerly healthy young individuals who died or became disabled from working in the textile industry.

## MATERIALS AND METHODS

The medical records of patients suffering silicosis due to denim sandblasting who were treated at our institution between 2001 and 2009 were reviewed. The following data were abstracted from the medical records: symptoms and age at presentation; gender; history of smoking; coexisting pulmonary conditions; daily, weekly, and total working times; cumulative exposure time to silica; results of pulmonary function studies; radiologic findings; and diagnostic methods. Chest radiographs were evaluated by a B-reader certified by the Turkish Labor Ministry and an experienced chest physician. Silicosis was defined as a chest radiograph with an International Labour Office classification of  $\geq 1/0$  in a worker with a history of exposure to silica dust.<sup>8</sup> No exposure assessments or worksite visits were performed.

Pulmonary function data included FVC, FEV<sub>1</sub>, FEV<sub>1</sub>/FVC, and diffusing capacity of the lung for carbon monoxide (DLCO). A restrictive pattern was defined as an FVC < 80% predicted and a normal or high FEV<sub>1</sub>/FVC ratio. An obstructive pattern was defined as an FEV<sub>1</sub> < 80% predicted and an FEV<sub>1</sub>/FVC ratio < 0.75. European Respiratory Society 1993 standards were used in pulmonary function testing.<sup>9</sup>

The vital status of each patient was determined by reviewing his/her medical records and by telephone interview with the patient or relatives, and follow-up data were obtained from visits to the clinic. Compensation status of the patients was recorded. Survival was determined from the date of diagnosis of silicosis to the date of death or the date on which the patient responded to the telephone call. Survival analysis was performed using the Kaplan-Meier method for univariate analysis.

## RESULTS

In total, 32 male patients diagnosed with silicosis due to denim sandblasting presenting at our institution over an 8-year period, from 2001 to 2009, were investigated. No patient was referred from his or her workplace. Sandblasting was undertaken at small-scale operations (< 10 workers) that were subcontracted by larger companies. Most of the patients were from different workplaces and some had worked at a number of these operations. The clinical characteristics of patients at the time of diagnosis are summarized in Table 1. Because of awareness regarding their work colleagues, six asymptomatic patients (18.8%) sought medical attention. The remaining 26 patients had respiratory symptoms. The patients were all previously healthy and reported no history of hospitalizations. They had not worked in other silicosis-causing jobs previously. In addition, none of them had hobbies with a silicosis risk.

Clinical classifications were based on exposure times and the clinical presentations of the patients. Of the 32 patients, 10 (31.3%) with a latency of < 5 years and rapid disease progression were classified as acute silicosis, 20 patients (62.5%) with a latency of 5 to

10 years and progressive disease were classified as having accelerated silicosis, and two patients (6.3%) with a latency of > 10 years and with relatively slow progression and insidious symptoms were classified as having chronic silicosis.<sup>1</sup> Of the 10 patients with acute silicosis, four (40%) died. Of the 20 patients with accelerated silicosis, two (10%) died. Time to death after initial exposure was 6.4 years in patients with acute silicosis and 9.4 years in patients with accelerated silicosis. Both of the patients with chronic silicosis are still alive.

Radiographic classification of the chest radiographs is summarized in Table 2. Two patients had pleural thickening and 15 patients had additional radiographic abnormalities, including pneumothorax, marked distortion of the intrathoracic organs, or TB.

Pulmonary function data are summarized in Table 3. In total, 18 patients (56.3%) had restrictive and eight patients (25%) had mixed (obstructive + restrictive) patterns in pulmonary functions. A further three patients (9.4%) had isolated reduction in DLCO and three patients (9.4%) had no detectable abnormality.

The initial case was diagnosed in 2001, but no further case was diagnosed until 2004. One case was diagnosed in 2004 and a further six cases in 2005, nine in 2006, eight in 2007, four in 2008, and three in 2009. Diagnosis was confirmed by open lung biopsy in three (9.4%), transbronchial biopsy in 11 (34.4%), and occupational history along with typical radiologic findings in 18 (56.3%) patients (Fig 1).

**Table 1—Characteristics at the Time of the Diagnosis of Silicosis**

Characteristic	Patients (N = 32)
Age, y	
Mean $\pm$ SD	31.5 $\pm$ 5.6
Median	30
Male gender	32 (100)
Smoking status	
Current/former	27 (84.4)
Never	5 (15.6)
Smoking history, pack/y	
Mean $\pm$ SD	13.9 $\pm$ 14.9
Median	10
Symptoms	
Dyspnea	21 (65.6)
Cough	16 (50)
Malaise	8 (25)
Weight loss	8 (25)
Chest pain	6 (18.8)
Asymptomatic	6 (18.8)
Coexisting pulmonary pathology	
TB <sup>a</sup>	4 (12.5)
Pneumothorax <sup>b</sup>	2 (6.3)

Data are presented as No. (%) unless indicated otherwise.

<sup>a</sup>Fifth patient diagnosed as silicotuberculosis during follow-up.

<sup>b</sup>Additional third patient was diagnosed with pneumothorax during follow-up.

**Table 2—Radiographic Findings Using the International Labour Office Classification**

Radiographic Finding	No. (%)
Small opacities	
Category 0: 0/-, 0/0, 0/1	...
Category 1: 1/0, 1/1, 1/2	5 (15.6)
Category 2: 2/1, 2/2, 2/3	5 (15.6)
Category 3: 3/2, 3/3, 3/+	19 (59.4)
Large opacities	
Type A	5 (15.6)
Type B	2 (6.3)
Type C	4 (12.5)

Time from initial exposure to diagnosis was  $5.9 \pm 3.1$  years (median, 5.5 years; range, 2-14 years) and the mean working time of the patients was 44.7 months. The daily, weekly, and total exposure times are shown in Table 4.

Of the initial 32 patients, 31 (96.7%) were followed up; one patient did not return after diagnosis and did not respond to phone calls. The mean follow-up period after the diagnosis of silicosis was  $29 \pm 20$  months (median, 29 months; range, 3-101 months). Of the surviving patients, 16 (64%) developed progressive massive fibrosis with marked functional impairment. The FEV<sub>1</sub> rates of 10 patients were <40% predicted. At the end of follow-up, eight patients had an FVC <40% predicted, and five patients had a DLCO <40% predicted. The decrease was 20.9% in FEV<sub>1</sub>, 17.8% in FVC, and 14.2% in DLCO. Table 3 shows the pulmonary functional impairment of patients. Table 5 shows the mean changes in lung function parameters per year of the three different clinical groups of silicosis. Changes in pulmonary function of the three clinical forms are displayed in Figure 2. During the last 6 months of 2009, six patients were

**Table 3—Pulmonary Function at Diagnosis of All Patients, at Diagnosis of Those Seen at Follow-up, and at the End of Follow-up**

Parameter	All Patients	Patients Seen at Follow-up	Patients at the End of Follow-up
FVC (% predicted)			
No.	32	21	21
Mean $\pm$ SD	65.3 $\pm$ 19	66 $\pm$ 17	53.7 $\pm$ 21
Median (range)	65 (25-103)	66 (33-103)	55 (25-88)
FEV <sub>1</sub> (% predicted)			
No.	32	21	21
Mean $\pm$ SD	62.3 $\pm$ 21	64 $\pm$ 20	49.3 $\pm$ 22
Median (range)	59 (21-103)	59 (32-103)	42 (26-88)
DLCO (% predicted)			
No.	30	18	18
Mean $\pm$ SD	64.8 $\pm$ 19	66.6 $\pm$ 18	55.6 $\pm$ 20
Median (range)	63.5 (29-101)	62 (38-101)	53.5 (24-100)

DLCO = diffusing capacity of the lung for carbon monoxide.

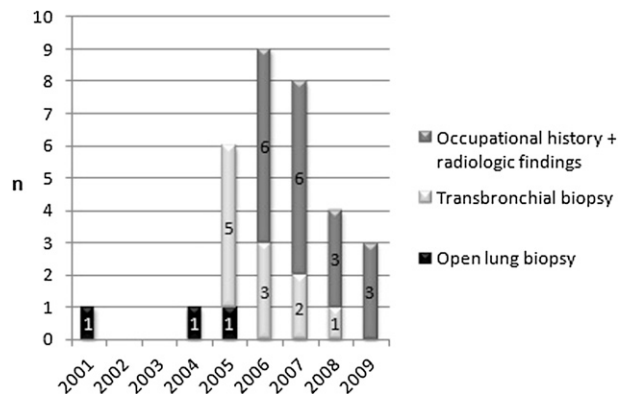


FIGURE 1. Number of patients diagnosed with silicosis, highlighting the changing diagnostic methods.

hospitalized with respiratory failure and one patient is on the waiting list for lung transplantation.

Of the original 32 patients, nine (28.1%) have been compensated for silicosis. A further seven patients (21.9%) are still waiting for compensation and one has had his compensation denied; the reason for the denial was that the patient presented with normal lung function. Six (19.4%) deaths were attributed to respiratory failure. Just two of the patients who died (two of six) were compensated before their deaths.

The 5-year survival rate after a diagnosis of silicosis was 69.2% (Fig 3). The estimated survival time (mean  $\pm$  SE) was  $78 \pm 8$  months (95% CI 62-94). Survival was associated with an initial FEV<sub>1</sub>  $\leq$  55% ( $P = .0128$ ), an initial FVC  $\leq$  55% ( $P = .0136$ ), and an initial DLCO  $\leq$  60% ( $P = .0352$ ) using univariate analysis. Mean survival from time of first symptoms was  $108 \pm 14$  months and the estimated 5-year survival was 62.6%. Mean survival from time of first exposure was  $200 \pm 23$  months, the estimated 5-year survival was 96.8%, and 10-year survival was 59.8%.

## DISCUSSION

The first case of silicosis was diagnosed in 2001. The patient had not worked in an environment known for causing silicosis and described himself as a textile worker. After detailed occupational questioning, it became clear that he was a denim sandblaster. At the time, this was an unknown, but growing, occupation performed to produce unique patterns on denim goods that were not possible to obtain through other procedures. Three years later when an additional textile worker was diagnosed with silicosis, we became concerned. In fact, recently published reports confirmed that an outbreak of silicosis was being reported.<sup>5-7,10,11</sup> Figure 1 reflects the change in the diagnostic approach of pulmonologists. The initial cases were diagnosed using open lung biopsy, which was later replaced by

**Table 4—Exposure Times of the Patients**

	Total Working Time, mo	Weekly Working Time, d	Daily Working Time, h	Total Exposure Time, h
Mean ± SD	44.7 ± 41.9	6.3 ± 0.6	10.6 ± 1.5	12,956.6 ± 12,111.7
Median	28.5	6	10	8,605
Range	9-180	5-7	8-14	7,088-46,950

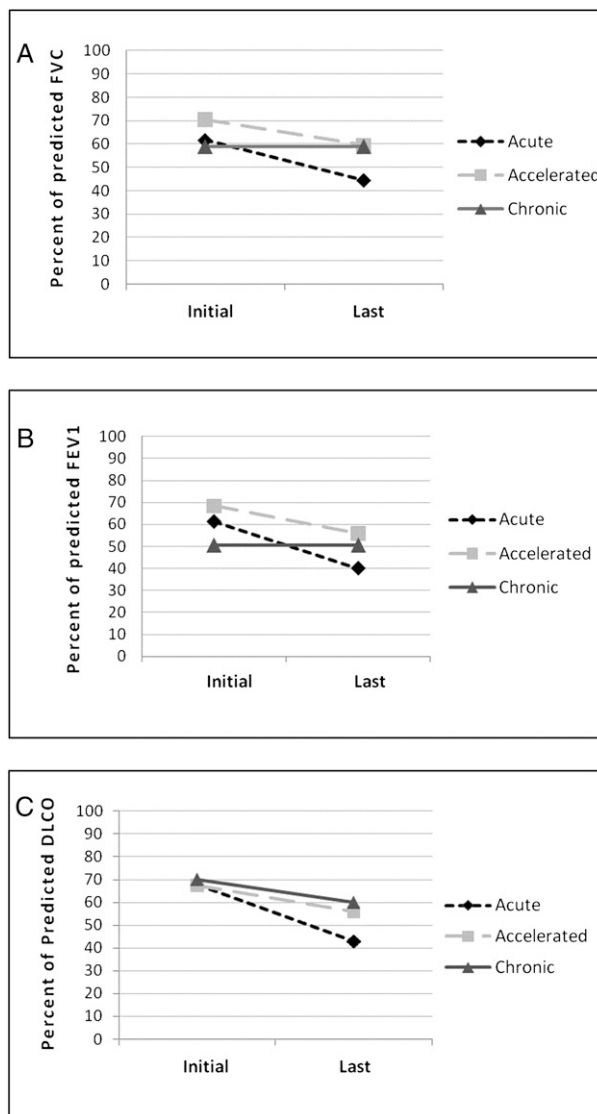
transbronchial biopsy. This was primarily performed to exclude granulomatous diseases, such as TB and sarcoidosis. Some of the initial patients were misdiagnosed as suffering from TB, which is prevalent among textile workers in Turkey. With an increasing number of patients with silicosis, pulmonologists made their diagnosis based on occupational history and radiologic changes. The increasing number of patients with silicosis and deaths among denim sandblasters alarmed the Turkish Thoracic Society. Turkish labor authorities were notified about the potential for catastrophe. Meanwhile, the Turkish media were used to draw attention to the dangers of this occupation. Many of the workers resigned after these health issues were highlighted and many small-scale workplaces closed. Finally, in March 2009, the Turkish Ministry of Health announced that sandblasting was prohibited. It is supposed that many other workers were exposed, but the number of the exposed workers is not known. It is likely that some of the exposed people will present with the disease in the coming years. Health and labor authorities should encourage workers/former workers to seek medical advice, which could be helpful in identifying new cases early.

Increased awareness surrounding denim sandblasting may prevent new silicosis cases in Turkey. However, it also raises concerns that the continued demand for “old-look” denim may simply result in the spread of this practice to other countries with more relaxed labor laws. Labor authorities should inspect such workplaces regularly. However, most of these small-scale workplaces are unregistered and/or their workers are undeclared, which means they do not possess an operating license or apply normal workplace regu-

**Table 5—Mean Changes in Lung Function per Year**

	Decrease in Predicted Values of Functional Parameters per Year		
	Acute Silicosis (n = 8)	Accelerated Silicosis (n = 11)	Chronic Silicosis (n = 2)
FVC (% predicted)	5.7 ± 3.2	3.3 ± 3.4	0.5 ± 0.7
FEV <sub>1</sub> (% predicted)	6.5 ± 3.9	5.6 ± 8.1	0.3 ± 0.4
DLCO (% predicted)	5.6 ± 5.8	6.3 ± 14.5	2.4 ± 2.2

Data are presented as mean ± SD. See Table 3 legend for expansion of abbreviation.



**FIGURE 2.** Changes in mean percentage values of predicted values of the three clinical forms of silicosis at initial and last visits. A, FVC. B, FEV<sub>1</sub>. C, DLCO. DLCO = diffusing capacity of the lung for carbon monoxide.

lations. This makes it more difficult to control this occupation. Limited employment opportunities and limited education of the workers, as well as the limited education of employers, are contributing to informal and unsafe working conditions.

Sandblasting denim is considered unnecessary; thus, the solution for denim sandblasting is to stop the practice, rather than to take protective measures. Of course, unsafe and unhealthy working conditions accompany many sandblasting jobs, but denim sandblasting is to satisfy a fashion trend, which can only be prevented by a global campaign against it. As far as we know, there have been no reports from other countries about denim sandblaster silicosis.

Chronic silicosis, the most common clinical form, typically occurs after long-term exposure to silica.<sup>12,13</sup>

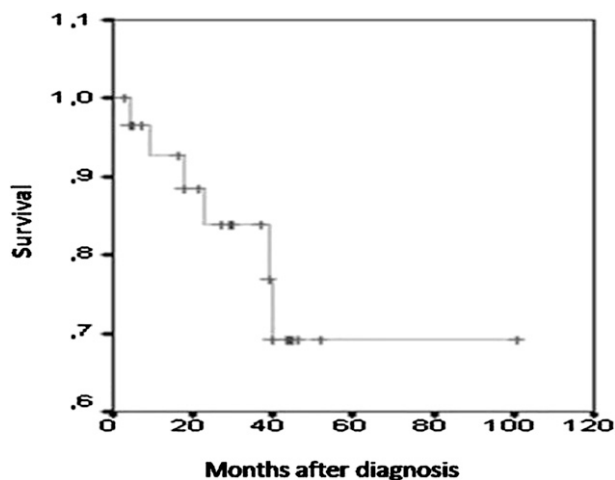


FIGURE 3. Kaplan-Meier analysis of survival of denim sandblasters with silicosis.

However, it was the least common form in our study population. The patients developed silicosis after a relatively short period, reflecting recent overexposure. Today, silicosis deaths among young individuals are still seen among sandblasters.<sup>14,15</sup> The use of silica for sandblasting has been restricted in most developed countries,<sup>16</sup> leading to the majority of silicosis-associated deaths occurring among older individuals (mostly  $\geq 65$  years).<sup>12,13,17</sup> In our study, the mean age of the individuals who died was 35 years. Even younger cases have been reported from other institutions.<sup>5,6</sup> Functional status at diagnosis was a predictor of survival. Factors including room size, dust levels, and protective measures might be associated with survival but were not assessed.

It is important to draw global attention to this occupation to prevent new silicosis cases in other countries. Sustained efforts must be made to increase awareness of denim sandblaster silicosis. Silicosis in young individuals after exposure in the textile sector suggests a lack of awareness of the hazards of silica outside traditional occupations associated with silicosis. However, deaths from silicosis suggest overexposure and unsafe working conditions, resulting from lack of control. There is no solution other than stopping this life-threatening procedure.

#### ACKNOWLEDGMENTS

**Author contributions:** Dr Bakan was the principal investigator of this study.

*Dr Bakan:* contributed to coordination and design of the study; data interpretation and statistics; drafting, writing, and approval of the manuscript.

*Dr Özkan:* contributed to design of the study, follow-up evaluation of the patients, and drafting of the manuscript.

*Dr Çamsarı:* contributed to radiograph evaluation, follow-up evaluation of the patients, and review and approval of the manuscript.

*Dr Gür:* contributed to follow-up evaluation of the patients, literature review, and review of the manuscript.

*Dr Bayram:* contributed to data interpretation, statistics, literature review, and writing and review of the manuscript.

*Dr Açıkmeşe:* contributed to secretarial assistance, follow-up evaluation of the patients, and drafting of the manuscript.

*Dr Çetinkaya:* contributed to radiograph evaluation, follow-up evaluation of the patients, and approval of the manuscript.

**Financial/nonfinancial disclosures:** The authors have reported to *CHEST* that no potential conflicts of interest exist with any companies/organizations whose products or services may be discussed in this article.

#### REFERENCES

- Petsonk EL, Parker JE. Coal workers' lung diseases and silicosis. In: Fishman AP, et al, eds. *Pulmonary Diseases and Disorders*. 4th ed. New York, NY: McGraw-Hill; 2008:967-980.
- Sherson D. Silicosis in the twenty first century. *Occup Environ Med*. 2002;59(11):721-722.
- Sevinc C, Cimrin AH, Manisali M, Yalcin E, Alkan Y. Sandblasting under uncontrolled and primitive conditions in Turkey. *J Occup Health*. 2003;45(1):66-69.
- Gur A, Kiyik M, Kilic L, et al. Silicosis in denim sandblasting textile workers (two case reports) [abstract]. *Eur Respir J*. 2005;26(suppl 49):979.
- Akgün M, Görgüner M, Meral M, et al. Silicosis caused by sandblasting of jeans in Turkey: a report of two concomitant cases. *J Occup Health*. 2005;47(4):346-349.
- Sahbaz S, İnönü H, Öcal S, et al. Denim sandblasting and silicosis two new subsequent cases in Turkey. *Tuberk Toraks*. 2007;55(1):87-91.
- Akgün M, Mirici A, Ucar EY, Kantarci M, Araz Ö, Görgüner M. Silicosis in Turkish denim sandblasters. *Occup Med (Lond)*. 2006;56(8):554-558.
- International Labour Office (ILO). *Guidelines for the Use of ILO International Classification of Radiographs of Pneumoconioses*. Revised edition. Geneva, Switzerland: International Labour Organization; 2000.
- Quanjer PH, Tammeling GJ, Cotes JE, Pedersen OF, Peslin R, Yernault JC. Lung volumes and forced ventilatory flows. Report Working Party Standardization of Lung Function Tests European Community for Steel and Coal, Official Statement of the European Society. *Eur Respir J*. 1993;6(suppl 16):5-40.
- Akgün M, Araz O, Akkurt I, et al. An epidemic of silicosis among former denim sandblasters. *Eur Respir J*. 2008;32(5):1295-1303.
- Cimrin A, Sigsgaard T, Nemery B. Sandblasting jeans kills young people. *Eur Respir J*. 2006;28(4):885-886.
- Rosenman KD, Reilly MJ, Kalinowski DJ, Watt FC. Silicosis in the 1990s. *Chest*. 1997;111(3):779-786.
- 't Mannetje A, Steenland K, Attfield M, et al. Exposure-response analysis and risk assessment for silica and silicosis mortality in a pooled analysis of six cohorts. *Occup Environ Med*. 2002;59(11):723-728.
- Centers for Disease Control and Prevention. Silicosis deaths among young adults. *MMWR Morb Mortal Wkly Rep*. 1998; 47:331-335.
- Suratt PM, Winn WC Jr, Brody AR, Bolton WK, Giles RD. Acute silicosis in tombstone sandblasters. *Am Rev Respir Dis*. 1977;115(3):521-529.
- Wagner GR. The inexcusable persistence of silicosis [editorial]. *Am J Public Health*. 1995;85(10):1346-1347.
- National Institute for Occupational Safety and Health, Division of Respiratory Disease Studies. The work-related lung disease surveillance report, 2007. Cincinnati, Ohio: US Department of Health and Human Services. 2008; DHHS (NIOSH) publication no. 2008-143a:53-94.