Pneumoconioses are a group of pathologic conditions resulting from inhalation of substances into the lungs. The predominant pneumoconioses are asbestosis, silicosis, and coal workers’ pneumoconiosis, which are caused by inhalation and deposition in the lungs of respirable asbestos fibers, silica dust, or coal dust, respectively. Except for rapidly progressive forms of silicosis, there is a latency period of up to 20 years between exposure and the development of clinically apparent disease. Severe pneumoconiosis can lead to lung impairment, disability, and premature death. Pneumoconioses are predominantly associated with chronic occupational exposure [1, 2]. This paper examines asbestosis and silicosis hospitalizations in North Carolina over a 10-year period.

Asbestosis

Asbestos is the name given to 6 naturally occurring fibrous minerals that have been used for many years in the manufacturing of many types of products because of their low cost and desirable qualities—such as heat and fire resistance, wear and friction characteristics, strength, and insulation capabilities. Use of asbestos boomed from the early 20th century to the mid-1990s; it was used in the manufacturing of pipes, coatings, flooring, friction materials, insulation, asphalt emulsions, gaskets, packings, plastics, roofing, and textile materials. From the 1930s through the mid-1990s, significant asbestos exposure sources existed for workers in North Carolina. The state had one of the largest concentrations of asbestos textile mills in the nation, and the state’s industries imported large quantities of asbestos from other countries, such as Canada and South Africa. To a lesser extent, asbestos was also actively mined in North Carolina. As a result of these activities, during the 20th century North Carolina was ranked among the top production states for asbestos [3-5].

After 1973, asbestos-related health concerns began to strongly affect demand, causing national production to stagnate. In 2002, the last asbestos mines in the United States closed. Asbestos has been phased out of most products, except for gaskets, friction products, and some roofing materials. Occupational exposures to asbestos still occur in the construction industry and in ship repair, particularly when asbestos materials are removed during renovation.


Gregory T. T. Dang, Nirmalla Barros, Sheila A. Higgins, Ricky L. Langley, David Lipton

BACKGROUND Asbestosis and silicosis are debilitating pulmonary conditions resulting from inhalation of asbestos fibers or silica dust.

PURPOSE We provide a descriptive analysis of asbestosis and silicosis hospitalizations in North Carolina to assess trends over a 10-year period.

METHODS Events were defined as inpatient hospital discharges during the period 2002–2011 with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code of 501 or 502. Using statewide discharge data for 2002–2011, we calculated asbestosis and silicosis hospitalization rates in North Carolina (by demographics, hospital length of stay, cost, and payment type) and compared them with national rates.

RESULTS In North Carolina, average annual age-standardized hospitalization rates for asbestosis and silicosis were 71.2 hospitalizations per 1 million residents and 6.2 hospitalizations per 1 million residents, respectively. Rates for asbestosis and silicosis decreased significantly (P<.01 for both conditions) between 2002 and 2011, by 46% and 67%, respectively. Men had significantly higher rates than women (P<.01), more than half of hospitalizations were among persons aged 65–84 years, and Medicare was the predominant payment source. The highest silicosis rates by county were clustered in Western North Carolina; no geographic patterns were observed for asbestosis. The estimated average annual cost statewide for these hospitalizations was $10,170,417 for asbestosis and $886,143 for silicosis.

LIMITATIONS ICD-9-CM misclassification and duplicate hospitalization records may have biased the observed rates of asbestosis and silicosis.

CONCLUSIONS Decreases in hospitalization rates in North Carolina may be due to misdiagnosis, underreporting, or the declining use of asbestos in industries. Obtaining complete exposure histories at diagnosis is useful for continued public health surveillance.
repairs, or demolition. Workers are also likely to be exposed to asbestos during the manufacturing of asbestos products and while doing automotive brake and clutch repair work [1, 6, 7].

Asbestosis occurs when airborne fibers are inhaled and irritate structures and tissues in the lungs. Several factors affect the initiation and progression of asbestosis, including the size and type of fiber, intensity and duration of exposure, history of cigarette smoking, and individual susceptibility. Once the disease process begins, it may progress regardless of whether there is continued exposure to asbestos; the disease eventually leads to severe fibrosis of the lungs that can cause breathing difficulties. Asbestos inhalation can also cause lung cancer and mesothelioma, the latter of which is a cancer that affects the protective membrane surrounding the lung and other organs. Other cancers associated with exposure to asbestos include gastrointestinal cancers [1]. There is no known treatment for asbestosis. Workers with this condition should be removed from exposure, and contributing factors, such as smoking, should be reduced or eliminated [8].

Silicosis
Silicosis results from inhalation of silicon dioxide, or silica, in crystalline form. Silica is a component of rocks and sand. Occupational exposures to silica occur across a broad range of industries, including mining, manufacturing, construction, maritime work, and agricultural industries. Exposure to silica can occur as part of common workplace operations involving the dissociation (crushing) of stone and rock products and in operations that use sand, such as glass manufacturing, foundries, and sand blasting [6, 9, 10].

Silicosis can be either acute or chronic. Acute silicosis is a rapidly progressive condition that occurs when workers are exposed to very high concentrations of respirable free silica dust. This condition can be life threatening, as the lungs become densely fibrotic and fill with fluid, making breathing difficult. In chronic forms of silicosis, which have a latency period of 2 to 10 years or longer, nodules form in the lung tissue. Chronic silicosis may be uncomplicated, when it is a mild form of the disease with fewer symptoms, or complicated, when it is a more serious form of the disease involving fibrosis of the lungs. Possible complications of silicosis include tuberculosis and pulmonary fungal diseases [8]. A report by the World Health Organization (WHO) has shown a link between silica exposure and lung cancer [11]. As with asbestosis, silicosis has no known treatment, and workers with this condition should be removed from the environment in which silica exposure is occurring.

Monitoring of Asbestosis and Silicosis
North Carolina has taken steps to monitor asbestosis and silicosis in the workplace. From 1938 to 2002, the North Carolina Division of Public Health operated the Dusty Trades program, which monitored exposure and carried out medical screening for workers exposed to asbestos and silica hazards. In addition, the North Carolina Division of Public Health has considered both asbestosis and silicosis to be reportable conditions since 1994, and it conducted case-based surveillance until 1998. Despite these efforts, data to address the burdens of asbestos and silica exposure among working adults in North Carolina have been limited since these pneumoconiosis surveillance programs ceased to function in 2002 [12]. In addition, efforts to examine these conditions in North Carolina are not recent or are limited in scope [13-17].

Asbestosis and silicosis are serious, debilitating conditions. Surveillance of these conditions is important for identifying and decreasing their burden in North Carolina, through targeted prevention strategies and regulatory enforcement programs. This paper provides a descriptive analysis of asbestosis and silicosis hospitalization trends in North Carolina, which can shed light on the current burden of asbestosis and silicosis on workers throughout the state.

Methods
We conducted a retrospective review of asbestosis and silicosis inpatient hospitalizations for a 10-year period (2002-2011) using data from the North Carolina Inpatient Hospital Discharge Database (NCIHDD) and from the National Hospital Discharge Survey (NCHS). The NCIHDD, which is managed by the North Carolina State Center for Health Statistics, contains case-specific discharge data for all patients admitted to and discharged from any nonfederal hospital facility in North Carolina. Data include information regarding demographics, hospital admissions, diagnostics, care, and payment. Analyses were performed on variables indicating sex, age, county of residence, length of hospital stay, payment source, and charges associated with the visit.

We adapted methods for case selection and calculation of age-standardized rates of asbestosis and silicosis from the Council for State and Territorial Epidemiologists (CSTE) data collection methods for the national occupational health indicator “hospitalizations from or with pneumoconiosis” [18, 19]. Cases were defined as all inpatient hospital discharges from 2002 to 2011 with a primary or contributing diagnosis of asbestosis (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] code 501) or silicosis (ICD-9-CM code 502) among North Carolina residents aged 15 years or older.

Annual rates were calculated via direct standardization, using US standard population estimates for the year 2000 [20]. These methods are consistent with the CSTE methods for calculating national occupational health indicators. The total number of hospital discharges for patients diagnosed with asbestosis or silicosis was divided by the annual US Census Bureau population estimate for North Carolina for the same calendar year. Population data were obtained from the US Census Bureau population estimates for the periods 2000-2009.
and 2010–2012 [21, 22]. Means were calculated across the 10-year period. Mean case counts by age group were calculated by dividing the total number of cases in each 10-year age group by the state population estimate for each age group.

SAS 9.3 software was used to perform Poisson regression to determine annual age-standardized rate trend significance for asbestosis and silicosis hospitalizations; 1-way analysis of variance (ANOVA), Tukey test, and 2 independent sample t-tests were used to compare annual age-standardized hospitalization rates for North Carolina, stratified by sex and age group, with rates for the United States. Mean rates of hospitalization by county were calculated across the 10-year period using the county of residence at the time of hospitalization. National data were only available for the years 2002–2010. Statistical significance was defined as a P-value less than .05.

**Results**

A total of 5,003 hospitalizations for asbestosis and 442 hospitalizations for silicosis were reported across the 10-year study period (2002–2011), for an average of 500 asbestosis hospitalizations and 44 silicosis hospitalizations per year. The mean annual age-standardized rate of hospitalization was 71.2 hospitalizations per 1 million residents for asbestosis (standard deviation [SD] = 16.0; range, 46.9–92.4) and 6.2 hospitalizations per 1 million residents for silicosis (SD = 2.1; range, 2.8–8.5). The age-standardized hospitalization rate for asbestosis steadily decreased from 2003 to 2011, after increasing from 2002 to 2003. The age-standardized hospitalization rate for silicosis showed steady decreases for the entire study period (2002–2011). The data showed a 46% overall decrease in the rate of asbestosis hospitalizations between 2002 and 2011, with an average rate change of 8% per year. For silicosis, there was a 67% overall decrease in the rate of hospitalizations between 2002 and 2011, with an average rate change of 10% per year. Poisson regression results showed that overall trends significantly decreased for both asbestosis (P<.01) and silicosis (P<.01) over the 10-year period (Figure 1).

Figure 2 compares annual age-standardized asbestosis and silicosis hospitalization rates in North Carolina with the annual age-standardized rates in the United States. For asbestosis, North Carolina's mean age-standardized hospitalization rate for the 9-year period 2002–2010 was 73.9 hospitalizations per 1 million residents, which was not significantly different from the US mean rate of 64.2 hospitalizations per 1 million residents (t = 1.15; P = .27). For silicosis, North Carolina's mean age-standardized hospitalization rate for the 9-year period 2002–2010 was 6.6 hospitalizations per 1 million residents, which again was not significantly different from the US mean rate of 4.6 hospitalizations per 1 million residents (t = 1.86; P = .08).

When data for North Carolina were stratified by sex,
annual age-standardized hospitalization rates for both conditions during the period 2002–2011 were significantly higher for men than for women. For asbestosis, men had a mean hospitalization rate of 66.7 hospitalizations per 1 million residents, and women had a mean hospitalization rate of 4.6 hospitalizations per 1 million residents ($t = -13.59; P<.001$). For silicosis, men had a mean hospitalization rate of 5.5 hospitalizations per 1 million residents, and women had a mean hospitalization rate of 0.7 hospitalizations per 1 million residents ($t = -8.88; P<.001$).

The mean age of asbestosis patients was 72 years (SD = 10.0; range, 32–101), and the mean age of silicosis patients was 68 years (SD = 11.6; range, 24–98). For asbestosis, 68% of hospitalizations occurred among individuals aged 65–84 years (Figure 3). Significant differences in mean hospitalization rates for asbestosis were found between the following age categories: 15–45 years, 55–64 years, 65–74 years, and 75–85+ years ($F = 182.08; P<.001$); the highest mean hospitalization rate was 48.7 hospitalizations per 100,000 residents for the age group 75–84 years (SD = 11.84; range, 30.56–64.95). For silicosis, 60% of hospitalizations occurred among individuals aged 65–84 years (Figure 4). The mean hospitalization rate for silicosis for those aged 15–64 years differed significantly from the rate for those aged 65–85+ years ($F = 16.35; P<.001$); the highest mean hospitalization rate was 3.3 hospitalizations per 100,000 residents for those aged 85 years or older (SD = 2.63; range, 0.70–7.85).

The 3 counties with the highest average rates of hospitalization for asbestosis during the period 2002–2011 were Washington, Rowan, and Haywood, which had 579.9, 402.7, and 271.0 hospitalizations per 1 million residents, respectively. The 3 counties with the highest average rates of hospitalization for silicosis were Yancey, Mitchell, and Swain, which had 165.2, 88.9, and 67.9 hospitalizations per 1 million residents, respectively.

When hospitalization cost trends during this time period were assessed, decreases were seen both for asbestosis hospitalizations ($t = 9.65; P<.001$) and for silicosis hospitalizations ($t = 3.74; P<.01$). The estimated average total statewide cost per year during the period 2002–2011 was $10,170,417 for asbestosis hospitalizations and $886,143 for silicosis hospitalizations. The estimated mean annual cost charged to individual patients who were hospitalized during the 10-year period 2002–2011 was $20,332.70 for patients with asbestosis (SD = $21,487; range, $524–$347,227) and $20,048 for patients with silicosis (SD = $25,505; range, $930–$299,854).

The major payment source for these hospitalizations was Medicare, which was documented as the primary payment source for 77% of asbestosis patients and 68% of silicosis patients. Private insurers that were not health maintenance organizations (HMOs) or preferred provider organizations (PPOs) were documented as the primary payment source.
FIGURE 3.  Mean Case Counts and Mean Rates of Hospitalization for Asbestosis in North Carolina by Age Group, 2002–2011

FIGURE 4. Mean Case Counts and Mean Rates of Hospitalization for Silicosis in North Carolina by Age Group, 2002–2011
for 11% of asbestosis patients and 13% of silicosis patients; HMOs and PPOs were documented as the primary payment source for 6% of asbestosis patients and 8% of silicosis patients; and workers’ compensation or other government insurance plans were documented as the primary payment source for 2% of asbestosis patients and 4% of silicosis patients.

During the period 2002–2011, the mean length of stay was 4.9 days for an asbestosis hospitalization (SD = 4.66; range, 1–94) and 4.9 days for a silicosis hospitalization (SD = 5.47; range, 1–87). More than half of patients (61% of those with asbestosis and 61% of those with silicosis) were hospitalized for 4 days or less.

Discussion

This study describes trends in annual hospitalization rates for asbestosis and silicosis in North Carolina over a 10-year period. Overall, the age-standardized hospitalization rates for asbestosis and silicosis decreased significantly during this period. Observed decreases in asbestosis hospitalizations may have been due to a decline in the use of asbestos in industries, leading to a decrease in worker exposure to asbestos. A 2006 US Geological Survey report [3] estimated that the amount of asbestos consumption in the United States was 51% of world production in 1950, but this percentage declined to 19% in 1970, 13% in 1975, 4% in 1985, and less than 1% in 2000. The decline in the rates of hospitalization for both asbestosis and silicosis may also result from cases being misdiagnosed as a result of incomplete patient exposure histories; because of the long disease latency period, the patient history needs to collect information about exposures over a sufficiently long timeframe. In addition, other conditions may present with similar chest radiograph findings; these conditions include sarcoidosis, pulmonary nodules in rheumatoid disease, carcinomatosis, military tuberculosis, deep fungal infections, and idiopathic pulmonary fibrosis [23].

North Carolina and the United States showed similar overall trends in mean annual age-standardized rates for asbestosis and silicosis hospitalizations throughout the 9-year period 2002–2010. Annual hospitalization rates were significantly higher for men than women for both conditions, for every year from 2002 through 2011. These rates are consistent with previous trends for diseases resulting from occupational exposures, and this finding is unsurprising since men constitute a greater proportion of the workforce in industries with potential asbestos and silica exposure [24, 25]. Higher hospitalization rates for both diseases were also found among older individuals, which is consistent with the latency periods associated with these conditions and with the decreased pulmonary reserves of elderly individuals.

The incidence of pneumoconiosis varies geographically, based largely on local industrial activities and migration of affected individuals [15, 16, 22]. There does not appear to be any clustering of asbestosis hospitalizations within North Carolina. Silicosis hospitalizations appear to have been concentrated in the westernmost part of the state, which had the highest county rates of silicosis. However, rates for observed silicosis hospitalizations over the 10-year period were small, so the apparent concentration of cases in this region may have been due to chance. As of 2012, estimated employment in asbestos-related industries in North Carolina was greatest in Guilford County, which had 365 jobs; Mecklenburg County, with 244 jobs; and Wake County, with 168 jobs. Estimated employment in silica-related industries for 2012 was greatest in Mecklenburg County, which had 5,605 jobs; Wake County, with 4,447 jobs; and Guilford County, with 1,232 jobs [26, 27]. Future ecological studies comparing these counties and measuring worker exposure within these industries longitudinally may yield interesting results.

Although decreases in the rates of asbestosis and silicosis hospitalizations were observed, exposure to asbestos and respirable silica still occurs. Asbestosis and silicosis are largely preventable by limiting exposure to asbestos fibers and respirable silica dust. Prevention begins with recognizing which tasks create airborne asbestos fibers and/or respirable silica dust and implementing controls to limit exposure before workers come into contact with these substances, in accordance with the federal standards for air contaminants [28]. Controls include exhaust ventilation to collect and remove dust from the environment, wet methods that limit production of airborne dust, and other engineering or administrative controls. Other hazard reduction steps include training and educating workers about the hazards of airborne asbestos and respirable silica dust, and making personal protective equipment available when other control measures are not feasible [28].

Currently, state programs help to monitor and reduce workplace exposure to asbestos and silica. Occupational exposure to asbestos and silica hazards in general industry and in construction is federally regulated by the Occupational Safety and Health Administration in the US Department of Labor. The Health Hazards Control Unit (HHCU) of the North Carolina Division of Public Health also administers an Asbestos Hazard Management Program in accordance with legal requirements [29]. This program accredits individuals who perform asbestos management activities (inspection, removal, and air monitoring), approves asbestos training courses, issues permits for asbestos removal projects and demolition notifications, inspects asbestos removal and demolition projects, reviews asbestos management plans for schools, and investigates citizens’ complaints [29].

Limitations

Multiple hospitalization records for patients were not de-duplicated during analysis, which may overestimate the number of hospitalizations. On the other hand, diagnoses made in federal facilities (eg, Veterans Affairs hospitals, military base hospitals, and mental hospitals), in outpatient
clinics, or in facilities in other states (for North Carolina residents) were not included in the calculations for this study, which may have led to underestimation of the number of hospitalizations.

Furthermore, because asbestosis and silicosis have a long latency period (10 to 20 years) from the time of exposure to apparent symptoms, hospitalization rates for a given year during the 10-year study period are not indicative of exposure to asbestos or silica during that year. Indeed, it may be many years before a reduction in exposure affects the rate of hospitalization for these conditions.

Finally, trend analysis using racial data would have been helpful to determine whether different racial groups were disproportionately affected by these conditions. However, information on race in hospital discharge files was not collected consistently via standardized methods until 2010. Therefore, racial data were not considered in this study.

Conclusions

Asbestosis and silicosis hospitalizations continue to be an important social and economic burden for workers and the health care system. Continuing state-level monitoring and regulation of occupational exposure to asbestos and respirable silica are necessary to help protect the health of workers. Although asbestos-related industrial activities may have decreased, naturally occurring asbestos deposits can be a public health concern with the encroachment of people and development into natural environments. North Carolina workers also continue to be exposed to respirable silica in a variety of industries and occupations. Physicians can help identify cases of asbestosis and silicosis by comprehensively recording occupational or environmental exposures when considering pneumoconioses in the differential diagnoses of lung diseases.


Nirmala Barros, PhD, MPH environmental epidemiology surveillance lead, Occupational and Environmental Epidemiology Branch, Division of Public Health, North Carolina Department of Health and Human Services, Raleigh, North Carolina.


David Lipton, MS, CIH industrial hygiene consultant, Occupational and Environmental Epidemiology Branch, Division of Public Health, North Carolina Department of Health and Human Services, Raleigh, North Carolina.

Acknowledgments

The authors wish to thank Allison Hayes, Jeff Dellinge, James Luecke, Marilyn Parker, and Mina Shehee of the North Carolina Department of Health and Human Services, Division of Public Health, and Aaron Fleischauer of the North Carolina Department of Health and Human Services, Division of Public Health, and the Centers for Disease Control and Prevention.

Disclaimer. The findings and conclusions of this report are solely those of the authors.

Potential conflicts of interest. All authors have no relevant conflicts of interest.

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