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Work-related asthma in cobalt-exposed workers

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ABSTRACT

Objective: Workers exposed to cobalt may develop two lung conditions, asthma or lung fibrosis. There is a relative lack of awareness of the risk of lung disease from cobalt exposure.

Methods: The state of Michigan requires physicians, and hospitals to report work-related asthma (WRA). A standardized telephone interview of each reported case was conducted. An industrial hygienist evaluated the reported cases's workplace, and a physician reviewed the results to confirm the diagnosis. This is a population-based case series of all workers in whom the exposure to cobalt was confirmed as likely responsible for WRA from 1988 to 2017. We also included an illustrative case report and data on the workplace evaluations.

Results: Of the 35 cases identified, 77% were males, 97.1% were white, and 62.9% had a history of smoking cigarettes. Fifteen (44%) cases were involved in manufacturing cutting tools and machine tool accessories. Symptoms improved in 28 cases (80%) when away from work. Fourteen cases (40%) had emergency department visits, while 10 (28.6%) had been hospitalized for breathing problems. Spirometry had been performed for 33 (94.3%) cases. Only 13 (37.1%) reported they were informed by a doctor that their asthma was work-related. Twenty-six inspections were conducted at 21 different workplaces, where 498 coworkers were interviewed, 55 (11%) of which had respiratory symptoms at work. Six workplaces were cited for cobalt air level higher than permissible limits. These inspections resulted in \$29,380 in penalties.

Conclusions: WRA secondary to cobalt is associated with significant morbidity. Most of the cases were unaware of their medical diagnosis.

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Cobalt; work-related asthma; public health surveillance

Introduction

Cobalt can have an adverse health effect on the heart, lungs, and skin. Workers exposed to cobalt may develop two lung conditions, asthma or lung fibrosis (hard metal lung disease). Cobalt induced asthma is an Ig-E mediated disease, although some patients have a positive lymphocyte proliferative response to cobalt (1). Hard metal lung disease is an interstitial pneumonitis, which can progress to fibrosis. The pathology consists of multinucleated giant cells that are found in the interstitium and bronchial lavage fluid.

In addition to case reports and case series of asthma among workers exposed to cobalt (2–5), studies of workers exposed to cobalt have reported on the prevalence of symptoms, reduced lung function and the increased risk of developing asthma (6,7). Older literature has reported that 5–15% of the cobalt exposed workforce may develop work-related asthma

(8,9). Exposure to cobalt during the manufacture of tungsten carbide tools, which contain 5–30% cobalt, particularly in the sintering phase when tungsten carbide is in a powder form, has the greatest potential for exposing workers to cobalt (10–12). Workers can also be exposed to cobalt in industries that use tungsten carbide tools to manufacture other products (13).

Despite the well-documented risk of work-related asthma (WRA) among cobalt-exposed workers, and that work is estimated to cause approximately 15% of new-onset asthma in adults, there is a relative lack of awareness among health practitioners in the United States of the risks and the burden of lung disease from work exposures (14).

Lack of recognition and under reporting to public health surveillance systems are important factors that effects patient care and limit the detection and correction of occupational hazards that cause and aggravate work-related asthma (15,16). Despite these limitations

public health surveillance systems provide estimates on the occurrence of work-related asthma (16). The objective of the surveillance program is to reduce the incidence and morbidity from WRA. The report of an index patient is regarded as a sentinel health event that may initiate a workplace investigation to identify other employees at risk from the same exposure and determine if any of those employees have symptoms compatible with WRA or have developed WRA since beginning to work at the facility. Outreach is provided to health care providers to assist in the recognition and management of WRA.

In this case series, we describe the characteristics of individuals who developed work-related asthma after exposure to cobalt at work, and who were reported to a population-based surveillance system in Michigan over 28 years from 1988 to 2017.

Methods

The methodology was a population-based case series of reported and then confirmed cases to a public health surveillance program, which used the reported cases to initiate public health intervention. All cases reported as WRA from exposure to cobalt during the years 1988 to 2017 were eligible for inclusion. Cases reported as having hard metal lung disease secondary to cobalt exposure were not included.

The State of Michigan instituted a surveillance program for work-related asthma (WRA) and silicosis in 1988 with financial assistance from the National Institute for Occupational Safety and Health (NIOSH) (16). The surveillance program is a joint project of the Michigan Occupational Safety and Health Administration (MIOSHA), the Michigan Department of Health and Human Services and Michigan State University. By law, physicians, hospitals, clinics, and employers are required to report any known or suspected occupational diseases to the state within 10 days (Michigan Public Health Code Article 368, Part 56, P.A. 1978, as amended). In the last 10 years efforts were expanded to encourage the reporting of all occupational lung disease.

The Division of Occupational and Environmental Medicine at Michigan State University administers the WRA surveillance program for the State of Michigan. Reports of WRA were received from physicians (private practice and physicians employed by companies), hospitals, emergency departments, and the single poison-control center in the state. In addition, all claims for respiratory disease filed with

the Michigan Workers' Disability Compensation Agency were reviewed.

Once these reports were received, the individual was contacted and a telephone interview with a standardized questionnaire was conducted (questionnaire is available at <https://oem.msu.edu/images/resources/Work-Related%20Asthma%20Questionnaire.pdf>). The information was collected: demographics; work history; smoking status; personal and family history of allergies; respiratory symptoms; and their relation to work; the individual's understanding of their medical condition; as well as the diagnostic workup for asthma (16). Copies of pulmonary function test results were obtained. Standard criteria were followed for the diagnosis of reversibility and bronchoprovocation testing (17). Standardized criteria developed in conjunction with other state-based surveillance programs and NIOSH were used to confirm a case was WRA and determine if the case was new onset (sensitizations or Reactive Airways Dysfunction Syndrome) versus work aggravated (18). Although it would be possible for a case, to have more than one occupational lung disease, none of the WRA cobalt cases had interstitial fibrosis on a chest radiograph. All medical testing was performed at the discretion of the treating physician and therefore was not standardized nor complete as occurs in case series from a single medical center.

An industrial hygienist from MIOSHA conducted workplace enforcement inspections at the companies where the workers developed their asthma. The scope of the inspections was to determine the facility's compliance with MIOSHA standards including the permissible exposure limit (PEL) for cobalt, and respirator, hazard communication, and injury and illness recordkeeping regulations. The NIOSH recommended exposure level and the MIOSHA enforceable eight-hour time weighted average (8 h-TWA) PEL is 0.05 mg/m³ (18), while the federal enforceable Occupational Safety and Health Administration (OSHA) 8 h-TWA PEL is 0.1 mg/m³ (19). The inspections also assessed whether there were additional workers with work-related respiratory symptoms or new asthma since beginning to work at the company (questionnaire is available at <https://oem.msu.edu/images/resources/Work%20Site%20Respiratory%20Symptoms%20Questionnaire.pdf>). This was done by reviewing the injury and illness logs that employers are required to maintain and administering a standardized confidential questionnaire to similarly exposed coworkers of the index case.

A physician board certified in both occupational medicine and internal medicine reviewed the results

Table 1. Demographics of workers with cobalt-induced work-related asthma, Michigan, 1988–2017.

	Number of workers	Percentage
Gender (male)	27	77.1%
Age, years 20–59 (median = 43)		
Race		
White	34	97.1%
African American	1	2.9%
Ever smoked	22	62.9%
Current smoker	9	25.7%
Average pack years 14.3 (0.25–34.5)		
History of attacks of bronchitis	16	45.7%
History of having pneumonia	7	20%
History of hay fever	5	14.3%
History of asthma	1	2.9%
History of COPD	2	5.7%
History of allergies	10	28.6%
Pets at home	14	40%
Family history of allergies	11	31.4%
Use of Personal Protective Equipment at work	20	57.1%
Applied for workers' compensation	19	54.3%
Workers' compensation status;		
Accepted	2	10.5%
Rejected	4	21.1%
Pending	13	68.4%

of the completed questionnaires, the medical records, including pulmonary function tests and the findings from the MIOSHA workplace inspections. The physician followed the NIOSH criteria to confirm the case (20). This information was also used to attribute the case as a cobalt-exposed WRA.

An illustrative case has been presented as a case report.

Descriptive statistics with percentages, means, medians and standard deviations were calculated. The chi square test was used to compare categorical variables between groups. Logistic regression analysis was employed to find the association between cobalt air monitoring levels and the percentage of workers having symptoms in the workplaces inspected. Statistical analysis was done using SAS version 9.4.

This work was approved by the Michigan State University's Institutional Review Board.

Results

Profile of cases

Michigan's surveillance program identified 35 workers with WRA secondary to cobalt. After review, all individuals were classified as having new onset asthma with exposure to cobalt. There were no individuals with work-aggravated asthma, or reactive airways dysfunction syndrome. There were another 17 individuals with hard metal lung disease who were not included; 16 of these individuals worked in different companies than the WRA cases; only one of the individuals with

hard metal lung disease had worked at a company that had one worker with WRA. None of the 35 WRA cases had radiographic changes of fibrosis. Eighteen physicians reported the 35 WRA cases (one physician 10 cases, one five cases, four physicians two cases each). Two of these physicians also each reported one hard metal lung disease case. Reporting physicians were not associated with the workplaces.

WRA cases were identified from 1988 to 2017 with a decrease from 20 during 1988–1997, to 11 during 1998–2007, to four during 2008–2017. WRA cases among cobalt-exposed workers were 1.6%, 0.8% and 0.5% of all confirmed WRA cases during the three respective time periods. Table 1 shows the demographics of the workers. Most were men (77.1%) in their 40's and were classified as white (97.1%).

Twenty-two subjects (62.9%) had a history of smoking cigarettes; nine (25.7%) were currently smoking. Twenty subjects (57.1%) reported wearing respiratory protection while working. Sixteen (45.7%) had not applied for workers' compensation benefits. Of the 19 who applied for benefits, two (10.5%) were awarded compensation, four (21.1%) were denied compensation and the remaining 13 (68.4%) were pending a decision at the time of interview.

Subjects had been in the company where respiratory symptoms began for a median duration of 3.5 years (range <1 to 29 years, mean 7 years) and worked at their current job for a median duration of one year (range <1 to 29 years, mean 4.7 years) before the development of respiratory symptoms (Table 2).

Sixty-five percent were workers involved in manufacturing tungsten carbide tools and 35% used those tools in manufacturing processes of other products (Figure 1). Most workers were in production occupations (80%); the remaining workers were in supervisory or office jobs and had not been production workers (20%) (Figure 2).

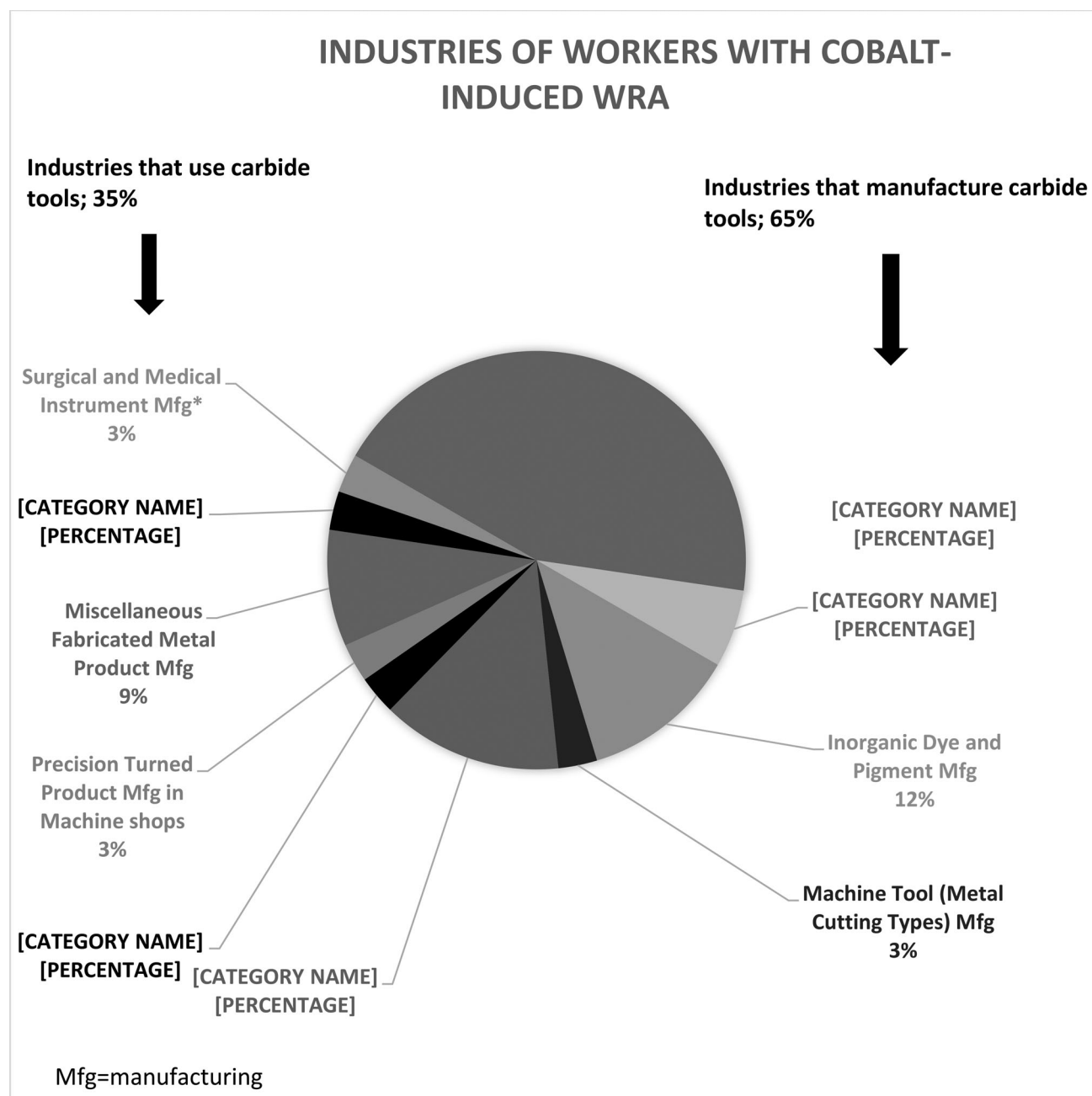
Respiratory symptoms

Commonly, symptoms worsened during work shifts ($n = 26$, 74.3%) and through the week ($n = 21$, 60%). Symptoms improved away from work in 28 workers (80%).

When asked about the diagnosis of their respiratory symptoms, 15 (42.9%) workers reported they were told they had asthma, 16 (45.1%) of the workers did not know the diagnosis of their respiratory symptoms, although they had the diagnosis of WRA in their chart, and four of them reported another diagnosis; COPD, pleurisy, pneumonitis, and the last worker

Table 2. Duration of time to the development of symptoms, diagnosis of asthma, and exposure to cobalt among workers with cobalt-induced work-related asthma, Michigan, 1988–2017.

	Median in years (Range, mean)
Duration at facility before developing respiratory symptoms	3.5 (<1–29, 7)
Duration at current job before developing respiratory symptoms	1 (<1–29, 4.7)
Duration of respiratory symptoms before diagnosis of asthma	1.5 (<1–24, 3)
Duration of exposure to cobalt after developing respiratory symptoms	2.5 (<1–27, 4.5)
Duration of exposure to cobalt after diagnosis of asthma	1 (<1–27, 1.5)

**Figure 1.** The figure shows the different industries of workers with cobalt-induced work-related asthma, categorized into industries that use carbide tools and those that manufacture carbide tools.

could not remember the name of his diagnosis but reported it was not asthma. Two of these 15 workers who knew they had asthma, did not know that their asthma was work-related.

Over half the respondents ($n = 22$, 57.1%) were aware of coworkers with similar symptoms. Thirty-one (88.6%) reported persistence of their symptoms and continued use of asthma medication; eight of

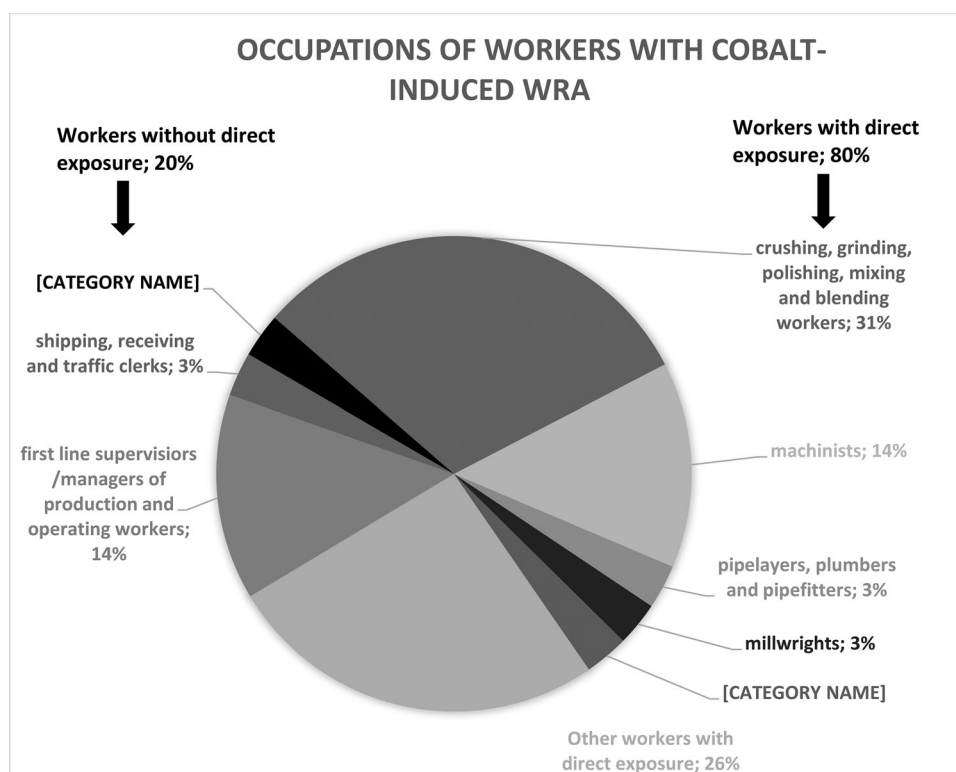


Figure 2. The figure shows the occupations of workers with cobalt-induced work-related asthma which are categorized into occupations without direct exposure and with direct exposure to cobalt.

35 (22.8%) were still exposed to cobalt, 23 (65.7%) were not exposed anymore and four (11.4%) were unsure about their current exposure. Figure 3 shows the reasons workers were no longer exposed to cobalt.

Pulmonary function testing

Spirometry had been performed by 33 (94.2%), pre-/post bronchodilator by 26 (74.9%) and a methacholine challenge test by four (11.4%) workers; 28 (80%) workers had either pre/post or methacholine challenge testing. Sixteen of 28 (57.1%) had either a positive pre-/post bronchodilator or a positive methacholine challenge test (Table 3).

Treatment

All 35 workers had sought medical treatment since starting the job and 34 (94.3%) required asthma medication. Fourteen (40%) had emergency department visits and 10 (28.6%) had been hospitalized for breathing problems. The median time between starting the job and the first emergency department visit was 1.5 years (<1 to 28 years) and 4.5 years (<1 to 32 years) until hospitalization.

Industrial hygiene follow-up

Twenty-six inspections were conducted at 21 different workplaces. Four of the workplaces had two WRA

cases and one had three WRA cases. Four hundred ninety-eight coworkers were interviewed during 23 of the 26 inspections. Fifty-five (11.0%) of the coworkers had daily or weekly chest tightness, shortness of breath, wheezing or new onset of asthma since beginning to work at the facility (Table 4). Because of the outstanding work demands, MIOSHA elected not to conduct inspections at three facilities where four WRA cases had worked.

Air monitoring for cobalt was conducted during 24 of the 26 inspections. Six companies were cited for having air cobalt levels above the Michigan PEL. The inspections resulted in 55 citations and a total of \$29 380 in penalties. Table 4 categorizes the companies according to the air monitoring results for cobalt. No statistically significant association was found between the number and percentage of symptomatic coworkers and cobalt air levels (>0.05 versus ≤ 0.05 mg/m³) in their workplace after controlling for smoking status (Odds Ratio = 0.85, 95% confidence interval = 0.45–1.60, $p = 0.60$).

Case report

A man in his 50s worked as a grinder at a carbide tool manufacturer. He had no history of asthma or breathing problems before starting work at his current job. He was a carbide grinder for 19 years in a

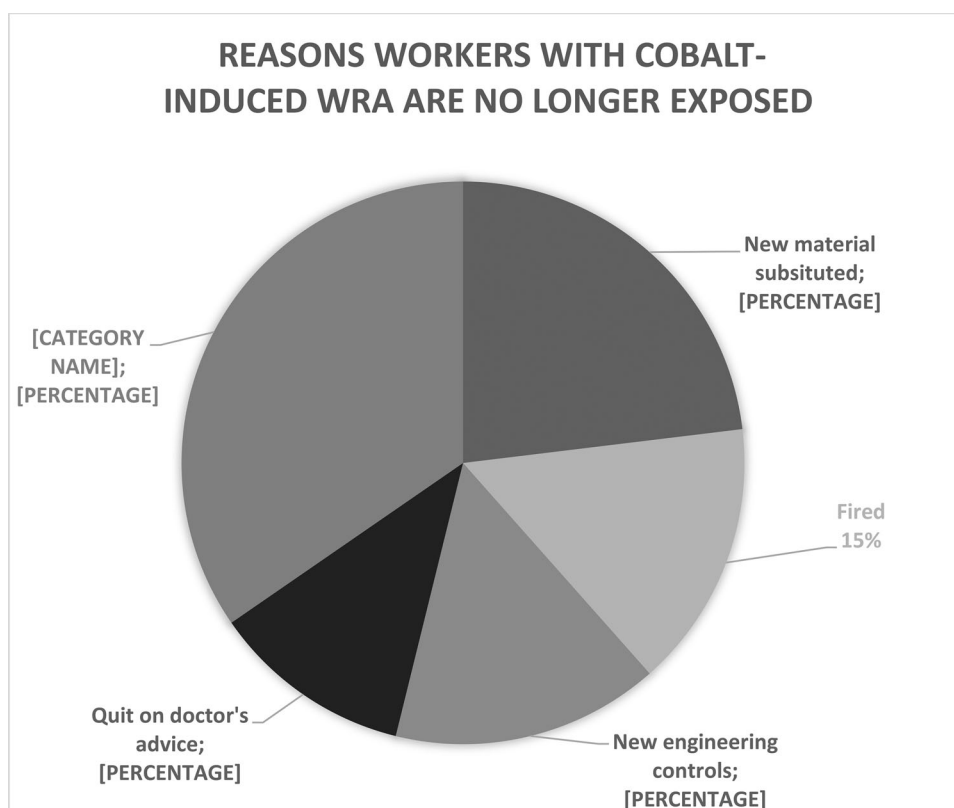


Figure 3. The figure shows different reasons reported by workers with cobalt-induced work-related asthma to why they are no longer exposed to cobalt.

Table 3. Spirometry results of workers with cobalt-induced work-related asthma, Michigan, 1988–2017.

Parameters	# Tested	Workers N (%)
Percent of predicted pre bronchodilator FEV1	33	
$\geq 80\%$		19 (57.6%)
$< 80\%$ and $\geq 50\%$		9 (27.3%)
$< 50\%$		5 (15.2%)
Percent of predicted pre bronchodilator FVC	33	
$\geq 80\%$		21 (63.6%)
FVC $< 80\%$ with FEV1 $\geq 80\%$ and FEV1/FVC ratio of > 0.75		1 (3%)
Pre-bronchodilator FEV1/FVC ratio of < 0.7		7 (21.2%)
Pre-bronchodilator FEV1/FVC ratio of < 0.7 and predicted FEV1 $< 70\%$		4 (12.1%)
Positive pre-/post bronchodilator (N = 26)		14 (53.8%)
Positive methacholine challenge (N = 4)		4 (100%)
Either positive pre-/post bronchodilator or methacholine challenge test (N = 28)		16 (57.1%)

Table 4. Workplace inspection air monitoring and coworker interview results by cobalt air levels, Michigan, 1988–2017.

Cobalt air level (mg/m ³)	# of inspections	# of workers interviewed	# (%) of workers with daily/weekly symptoms or diagnosis of asthma ^a
< 0.05	18	236	27 (11.4%)
≥ 0.05	6 ^b	223	23 (10.3%)
Not Measured	2	39	5 (12.8%)
Total	26 ^c	498	55 (11.0%)

^aSymptoms included chest tightness, shortness of breath and wheezing or the diagnosis of asthma was made after they started their job at current location.

^bFive companies were above the federal OSHA PEL of 0.1 mg/m³.

^cTwenty-six inspections in 21 different companies.

company and then moved to another the company with the same job, where he worked for another 3 years before he developed chest tightness, shortness

of breath, wheezing, and chest tightness. His symptoms were worse at work and improved away from work. He reported using personal protective

equipment at work. He never went to the emergency room or was hospitalized due to his respiratory symptoms. He was seen by his primary care physician within one year of the onset of his respiratory symptoms and was referred to a pulmonologist within the same year. Spirometry showed FVC 2.85 liters, predicted 57%, FEV1 1.57 liters, predicted 38%, and FEV1/FVC ratio of 55%. Post bronchodilator spirometry showed a 17% improvement in his FEV1. He was started on inhaler treatment on the first visit with his pulmonologist. The letter to the primary care physician, who had referred the patient, stated that occupational exposure to tungsten carbide can be an etiology to his adult-onset asthma and indicated he had told the patient to see him in six months to a year unless his symptoms worsened. The patient's symptoms continued to worsen despite treatment, and he was prescribed multiple courses of oral corticosteroids by his primary care physician over a period of three years. The patient saw the pulmonologist three years after his initial visit. The pulmonologist wrote "I have again clearly discussed with him the fact that dust, fumes and smoke will aggravate his condition and he may need to reassess his current work environment." The patient continued to work another three months and then took a two-week medical leave from work. His respiratory symptoms markedly improved and his FEV1 rose to 3.06 liters, 75% predicted. The patient then applied for workers' compensation and was put on disability leave. His workers' compensation application was pending at the time of the interview. His symptoms completely resolved one month after he stopped working.

Two MIOSHA inspections were done, one at his previous employer and the second at his current one. The inspection of his previous employer found that the cobalt air level was below the PEL ($<0.05 \text{ mg/m}^3$). The company was cited for violations of the hazard communication standard. Thirty coworkers were interviewed, four (13.3%) of the coworkers were bothered at work by weekly/daily chest tightness, shortness of breath or wheezing.

The results of the inspection of his current employer, led to the company being cited for a cobalt air level above the allowable PEL ($>0.05 \text{ mg/m}^3$), inadequate ventilation control, and inadequate hazard communication. Twelve coworkers were interviewed, three (25%) of the coworkers were bothered at work by weekly/daily chest tightness, shortness of breath or wheezing.

Discussion

Over a 28-year period, 35 workers with work-related asthma were reported to the state surveillance system.

The number of cases of cobalt exposed WRA decreased from 20 cases (1.6% of all WRA cases) from 1988 to 1997, to 11 (0.8%) from 1998 to 2007, to four (0.5%) from 2008 to 2017. A possible reason for this decrease was the decrease in the number of workers in Michigan exposed to cobalt. Most of our workers worked in the manufacturing of tungsten carbide tools, especially cutting tools and machine tool accessories (44%). According to the United States Census Bureau, the number of establishments in cutting tools and machine tool accessories manufacturing in Michigan in 2005 was 316 and the number of employees was 6,361, while in 2015, there were 220 establishments and 4,998 employees (21). We also had five workers (14%) who were exposed in the motor vehicle parts manufacturing industry. WRA secondary to cobalt in metalworkers has been reported previously in a case series in England, where 14 individuals worked in an automotive engine valve manufacturer (22).

Michigan is one of five states with an occupational respiratory disease surveillance program. All of these surveillance programs have been funded by NIOSH and follow a similar methodology of surveillance. From 1993 to 2015, two cases of cobalt WRA were reported in Massachusetts and two in New York. None were reported in California or New Jersey (23).

Twenty percent of the cases were non-production employees with limited exposure to cobalt. For example, one worked as a cutting tool and machine tool accessory purchasing agent. This underscores an important point for physicians, who should consider workplace exposures in new-onset asthma even if the patient's occupation might seem unlikely to have asthma-causing exposures. A consensus statement from the American College of Chest Physician outlined five questions healthcare providers should ask every adult patient with asthma related to the timing of symptoms and work (24). A thorough occupational history including details about daily routines rather than solely the position in industry or job title of workers are critical elements in the identification and diagnosis of WRA.

Among the 35 individuals reported, the median duration of symptoms before the diagnosis of work-related asthma was one and a half years, and the median duration of continued exposure to cobalt after a diagnosis of WRA was one year (Table 2). The duration of symptoms before the diagnosis was as long as 24 years and the duration of exposure after the diagnosis of WRA was as long as 27 years (Table 2). Other studies have reported an average delay of 3.2 to

4.9 years to the diagnosis of occupational asthma (7,25). Consensus statements and studies have attributed 10–55% of new-onset asthma to occupational exposures (11,24–26). Cobalt has been associated with occupational asthma with prevalence rates of 5–15% in workforces exposed to cobalt (8,9). A study of workers exposed to cobalt in a cobalt smelting plant, found a 5-fold increased risk of asthma in workers when compared to non-exposed workers (27). Despite evidence regarding the risks of occupational exposures as a contributor to the incidence of new-onset asthma, delay in diagnosis continues to occur. The sooner an individual is diagnosed with work-related asthma and removed from the exposure, the better the prognosis for that individual to either improve or have total remission of their asthma symptoms (15,28).

The number of companies with cobalt levels above the PEL in the three time periods were two of 13 (15.4%) in 1988–1997, one of eight (12.5%) in 1998–2007 and three of three (100%) in 2008–2017. There was an increase in the percentage of companies above the PEL over time identified the Michigan surveillance system. Although the number of tool manufacturers decreased in Michigan, there were still approximately 200 and we hypothesize this illustrates the surveillance system being able to increasingly better identify companies with higher exposures, as opposed to worsening conditions in companies using cobalt.

During most of the MIOSHA workplace enforcement inspections, air monitoring for cobalt was conducted and coworkers exposed to cobalt completed a respiratory symptoms questionnaire. Six workplaces had cobalt air levels higher than the Michigan OSHA PEL. This outcome shows the usefulness of a surveillance program to detect workplaces that are not in compliance with workplace standards. Most of the workplaces where air monitoring for cobalt was conducted were within the PEL. Yet even when companies were below the PEL, symptomatic coworkers were identified. Fifty-five symptomatic coworkers were identified who were bothered at work with daily or weekly chest tightness, shortness of breath or wheezing or were diagnosed with asthma after starting their job at the current location, consistent with work-related asthma. Although all 55 symptomatic coworkers were unlikely to have work-related asthma from cobalt, if one used this number as an estimate of under reporting, there were up to another 1.57 times as many individuals with work-related asthma from cobalt. Workers who left these companies because of respiratory health symptoms

or symptomatic workers at other companies using cobalt that were not inspected would increase the estimate of under reporting.

There was no correlation between the number and percentage of symptomatic coworkers and cobalt air levels in the workplaces. One possible explanation to the lack of correlation between the number of symptomatic workers and cobalt air level is that the air level measurements represent a single point in time, the day the OSHA inspector did the measurement while symptoms represent exposures over a prolonged period of time, where cobalt air levels may vary over time, especially during spills/leaks/peak exposures or equipment malfunctions. It is also possible that the existing OSHA air standard is not low enough to protect against the development of asthma. Therefore, assessment of symptoms in coworkers offered additional information that can be used to assess the respiratory health of workers even when air-monitoring levels are within permissible limits. The OSHA 300 Log that an employer with ten or more employees is required to maintain ideally would also help identify work-related respiratory illness at the facility. However, only two of the 26 companies listed three workers with respiratory symptoms. This contrasts with the 55 workers identified from interviews bothered at work by daily or weekly chest tightness, shortness of breath, wheezing or new-onset asthma since working at the facility. None of the three workers listed on the OSHA log completed a coworker questionnaire.

WRA is associated with significant morbidity (29). Fourteen out of the 35 (40%) workers had emergency department visits and 10 (28.6%) had been hospitalized for breathing problems. Despite the high morbidity of WRA, only about half of the workers (19, 54.3%) identified in the Michigan surveillance system applied for workers' compensation benefits and only two of 19 (10.5%) were actually awarded workers' compensation benefits although for 13 (68.4%) their application was pending.

The current study has limitations. The reporting physician made the diagnosis of WRA based on history. No specific antigen challenge testing was performed and it is possible that some of the subjects could have non-work-related asthma or have WRA from other exposures found in these workplaces such as metal working fluids. However, final determinations for including a case was based on a standardized telephone interview, review of medical records and review by a board-certified occupational and environmental physician. Of the 28 individuals (80%) who

had testing to document hyper-reactivity only 57% were positive, and there is the possibility that some individuals had irritative symptoms in relation to work but not asthma. The diagnosis of asthma and work-related asthma in the individuals reported in this case series represent standard practice in the United States. A major limitation is that there is both under recognition and under reporting of WRA by health care providers. For overall occupational disease, there is 100% reporting from hospitals and emergency departments, 15–33% reporting from occupational clinics, 0.6% reporting from companies, and 0.3% reporting from licensed physicians. We have no data or reason to believe that the cases reported differ from those not recognized or reported but given the degree of cases presumed to be missed, one cannot be sure how representative the cases are that were identified in the surveillance system.

Conclusions

Manufacturing of metalworking machinery was the most common industry associated with the development of WRA secondary to cobalt among Michigan workers. A large majority of subjects have chronic and long-standing symptoms. As reflected by frequent ED visits and hospitalizations, WRA secondary to cobalt was associated with significant morbidity and high healthcare utilization. Continuing efforts are needed to increase the awareness and compliance with public health reporting requirements, and education of healthcare providers to consider work-related asthma in all adults with asthma. The routine inclusion of the specific questions as recommended by the CHEST consensus statement (15) by clinicians as part of the evaluation of all adults with asthma would be an important first step to decreasing morbidity in individual patients. If the recommendation to comply with public health reporting were also followed then potentially there would be decreased morbidity in coworkers because of improvement in the working conditions where exposure had occurred.

Declaration of interest

All authors declare that they have no conflict of interest.

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