

Work-Related Asthma Among Health Care Workers: Surveillance Data From California, Massachusetts, Michigan, and New Jersey, 1993–1997

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Background Asthma morbidity has increased, posing a public health burden. Work-related asthma (WRA) accounts for a significant proportion of adult asthma that causes serious personal and economic consequences.

Methods Cases were identified using physician reports and hospital discharge data, as part of four state-based surveillance systems. We used structured interviews to confirm cases and identify occupations and exposures associated with WRA.

Results Health care workers (HCWs) accounted for 16% ($n = 305$) of the 1,879 confirmed WRA cases, but only 8% of the states' workforce. Cases primarily were employed in hospitals and were nurses. The most commonly reported exposures were cleaning products, latex, and poor air quality.

Conclusions Health care workers are at risk for work-related asthma. Health care providers need to recognize this risk of WRA, as early diagnosis will decrease the morbidity associated with WRA. Careful product purchasing and facility maintenance by health care institutions will decrease the risk. *Am. J. Ind. Med.* 47:265–275, 2005.

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INTRODUCTION

Asthma is a serious, chronic disease recognized as a critical public health problem in the United States. Morbidity and mortality associated with asthma has increased markedly during the last several decades [Chan-Yeung, 1995; Mannino et al., 1988, 2002; Arif et al., 2002; Oguntomilade et al., 2002]. The proportion of adult new-onset asthma that is work-related has been estimated between 5% and 29% [Milton et al., 1998; Blanc and Toren, 1999; Blanc et al., 1999; Kogevinas et al., 1999; Bakke and Gulsvik, 2000; Mannino, 2000; Karjalainen et al., 2001]. The American Thoracic Society estimated the occupational contribution to the population burden of adult asthma as 15% [American Thoracic Society, 2003].

Work-related asthma (WRA) may have serious consequences for those affected. In a Canadian study, persons with new-onset asthma associated with work were more likely to be hospitalized than other workers [Liss et al., 2000]. Individuals with WRA may become sensitive to a variety of exposures that may exacerbate breathing problems even when away from work, and some change or leave careers with serious personal and economic ramifications [Cannon et al., 1995]. Direct and indirect costs attributable to WRA in the United States were estimated at \$1.6 billion per year [Leigh et al., 2002].

As an industry, health services is growing at twice the rate of the overall economy and the number of health care workers (HCWs) continues to increase. This sector's projected 2.5% average annual employment growth rate will yield 2.8 million new jobs by 2010 [Berman, 2001]. The Bureau of Labor Statistics projects big increases among home health care aides (62%), medical assistants (57%), and nurses (26%) [Bureau of Labor Statistics, 2000].

Information about biological, chemical, and ergonomic hazards for HCWs has become more available in the last 20 years [Bermel, 1983; Omenn and Morris, 1984; Patterson et al., 1985; Emmett and Baetz, 1987; NIOSH, 1988; Behrens and Brackbill, 1993; Collins and Owen, 1996; Aiken et al., 1997; Messing, 1998; Slaterry, 1998; Charney, 1999; Lipscomb and Borwegen, 2000; Quinn et al., 2000; Simpson and Severson, 2000; Tait et al., 2000; Clarke et al., 2002; NIOSH, 2002; Nygren et al., 2002]. Occupational injuries and illnesses have increased in health care while they have continued to decline in the workforce as a whole [NIOSH, 2002]. However, WRA among HCWs has not been well documented in the United States, with the exception of asthma associated with latex allergy [Bubak et al., 1992; Kelly et al., 1996; Charous et al., 2002; Dillard et al., 2002].

To characterize WRA cases among HCWs and identify prevention opportunities, we present data in this study from four states (California, Massachusetts, Michigan, and New Jersey) that conduct WRA surveillance as part of the Sentinel Event Notification Systems for Occupational Risks (SENSOR) Program.

METHODS

In 1988, Massachusetts, New Jersey, and Michigan received funding from the National Institute for Occupational Safety and Health (NIOSH) to establish statewide surveillance systems for WRA using the SENSOR model. In 1992, California also received funding. Although New Jersey was not funded for the third 5-year funding cycle beginning in 1997, it continued to participate. The SENSOR model is based on the concept of the sentinel health event which is "a preventable disease, disability or untimely death whose occurrence serves as a warning signal that prevention efforts have failed and others may be at risk [Rutstein et al.,

1983]." Using surveillance data, industries, occupations, worksites, and exposures can be identified and targeted for intervention.

Case Ascertainment

The primary source of data for all four states was physician reports. In these states physicians are required by state laws to report cases of asthma caused or aggravated by workplace exposures. In addition to patient demographic information, physicians provide information on the employer and suspected asthma-causing agent. Physician reports were actively solicited through newsletters and ongoing education for the medical community. In California, cases of WRA were identified through Doctor's First Reports (DFRs) of Occupational Injury or Illness, a statewide reporting system tied to physician reimbursement. California labor code mandates that physicians report medical services for known or suspected occupational illnesses or injuries within 5 days of providing care.

In addition to physician reports, Massachusetts, Michigan, and New Jersey periodically reviewed hospital discharge data for cases of WRA and states' workers' compensation systems data for claims filed for WRA. Michigan and New Jersey, but not Massachusetts, identified significant proportions of cases using hospital discharge data for the time period reported in this paper (18% and 13%, respectively). Michigan also queried coworkers of index cases to identify additional cases. Workers' compensation data have not been useful for identifying WRA cases because there is no specific code for asthma in the workers' compensation system data.

Case Follow-up

Each state conducted telephone interviews using standardized questionnaires to confirm and obtain more information on reported cases. In addition, Michigan and New Jersey reviewed medical records. Information collected was also used to distinguish between work-related exacerbations of preexisting asthma (work-aggravated asthma) and asthma induced by workplace exposures (new-onset asthma). New-onset asthma was further classified as occupational asthma (with known or unknown inducer) or reactive airways dysfunction syndrome (RADS), a condition involving persistent asthma symptoms following a one-time acute exposure to irritants; this classification scheme has been presented previously [Jajosky et al., 1999]. The exposure(s) identified by the cases were considered known asthma inducers if they had been previously documented in the scientific literature to cause asthma [Chan-Yeung, 1995], and were coded as asthmagens in the Association of Occupational and Environmental Clinics (AOEC) database [Hunting and McDonald, 1995]. Up to three suspected agents were coded and included for each case.

Analysis

All confirmed cases of WRA from 1993 to 1997 were included in the analysis. Industry data were coded using the 1987 Standard Industrial Classification (SIC) codes and occupation data were coded using the 1990 US Bureau of the Census (COC) codes. Industry and occupation information was reviewed to identify HCWs. Our definition of “health care worker” included all cases employed in the health care industry (SIC = 8000–8099), and cases with occupation codes identifying HCWs regardless of industry (COC = 084–089, 095–099, 105, 203–208, 445–447). These codes were selected because they represented the wide variety of occupations and industries in which HCWs were employed, including schools (SIC = 8211), ambulance services (SIC = 4119), and manufacturing. This ensures that the definition of “health care worker” is not limited to physician or nurse.

Comparisons between HCWs and non-HCWs were performed using chi-square statistics. A significance level of $P = 0.01$ was used. As a proxy for relative risk, we compared the proportional distribution of HCWs among the confirmed cases to the proportion of HCWs within the general workforce in the four states.

RESULTS

Between January 1, 1993 and December 31, 1997, the four SENSOR states confirmed 1,879 cases of WRA. Of these, 305 (16%) were identified as HCWs based on our definition. All but 8 cases ($n = 297$, 97%) worked in settings classified as Health Services, SIC 80, with the greatest number ($n = 192$, 63%) working in hospitals (Table I).

HCWs accounted for the greatest number of cases in three of the four states: 32% ($n = 92$) of all the WRA cases in

Massachusetts, 18% ($n = 29$) in New Jersey, and 17% ($n = 112$) in California. In Michigan, HCWs were second, comprising 9% ($n = 72$) of the cases (Table II). For comparison purposes, the last column of Table II also presents the number of workers employed in the health sector in each of the four states in 1995, the mid-year of the 5-year analysis. In all four states, the percentage of cases that were HCWs exceeded the percentage of health sector workers in each state (1995, SIC = 80) [Bureau of Labor Statistics, 2002].

Almost 91% of the cases ($n = 279$) were reported to the state surveillance systems by physicians. Eight percent ($n = 23$) were identified by review of hospital discharge data. The three remaining cases were identified from either workers compensation records ($n = 1$) or index case follow-up ($n = 2$).

Characteristics of the 305 HCWs may be compared to those of the 1,574 non-HCWs reported to the surveillance systems during this period. The median age of HCWs was 41 years compared to 42 years for non-HCWs. The HCWs were significantly more likely to be female ($n = 284$, 93%, $P \leq 0.01$) and white ($n = 241$, 79%, $P \leq 0.01$) compared to non-HCWs ($n = 788$, 50% female and $n = 1,134$, 72% white). More than half ($n = 160$, 52%) of the HCWs filed workers' compensation claims, significantly higher than non-HCWs ($n = 598$, 38% ($P \leq 0.01$)). Of those who filed claims, HCWs were significantly more likely than non-HCWs to be awarded benefits (46% vs. 35%, ($P \leq 0.01$)).

The HCW cases were also reviewed regarding exposures associated with their symptoms; the frequencies of exposures reported by ten or more cases are shown in Table III. At least one agent was coded for each case. Thirty percent of cases reported multiple exposures. Overall, the most commonly reported exposure was cleaning products (24%). Cleaning

TABLE I. Number and Percent of Work-Related Asthma Cases Among Health Care Workers by SIC* Code—California, Massachusetts, Michigan, and New Jersey, 1993–1997

SIC code	Industry	Number of cases	Percent (%)
806	Hospitals	192	63
8011, 8049	Offices and clinics of doctors and health practitioners	44	14
805	Skilled nursing care facilities	17	6
8021	Offices and clinics of dentists	12	4
8071	Medical laboratories	7	2
8082	Home health care services	7	2
8211	Elementary and secondary schools	4	1
4119	Local passenger transportation (ambulance)	4	1
8093	Specialty outpatient facilities	4	1
8092	Kidney dialysis centers	2	<1
	Other ^a	12	4
Total		305	100

*SIC—Standard Industrial Classification.

^aIncludes universities, research institutions, veterinary services, medical service plans, etc.

TABLE II. Number and Percent of Work-Related Asthma Cases by State—California, Massachusetts, Michigan, and New Jersey, 1993–1997

State	Total number of WRA cases	Number of health care workers	Health care workers as a percent of cases (%)	Health care workers ^a as a percent of workforce (%) (and number)
California	663	112	17	7 (851,300)
Massachusetts	292	92	32	11 (315,700)
Michigan	759	72	9	8 (350,700)
New Jersey	165	29	18	9 (307,700)
Totals	1,879	305	16	8 (1,825,400)

^aHealth care workers defined as employed in SIC = 80, Health Services (97% of all cases in this analysis).

products (exposures coded 322.00–322.33 in the AOEC coding, <http://www.aoec.org/aoeccode.htm>) included ammonia, bleach, carpet cleaners, disinfectants, floor strippers, and several recognized asthmagens (e.g., quaternary ammonium compounds). Exposure to latex, a known asthma inducer, accounted for 20% of the case reports. Other known asthma inducers reported by HCWs included glutaraldehyde (9%) and formaldehyde (5%). Indoor air pollution was reported by 12% of cases. Indoor air pollution was coded if the case reported poor indoor air quality or lack of ventilation. Specific agents associated with poor indoor air quality such as molds, chemical fumes or vapors, or smoke, were coded separately if this information was provided. Molds, some of which are known asthma inducers, were the reported exposure for 5% of cases. Exposures identified by HCWs differed from non-HCWs. Non-HCWs most frequently reported exposures to (in order of frequency) miscellaneous chemicals, cutting oils, indoor air pollution, dust, and smoke.

Table IV lists the most frequently reported exposures by occupation. Frequencies in each agent category represent the number of HCWs with WRA that reported that particular

agent. Nurses were most affected by latex (33%), cleaning products (21%), and glutaraldehyde and formaldehyde, together (19%). Office workers and aides/therapists, respectively, identified miscellaneous chemicals, paints, solvents, and glues (31%, 29%), followed by cleaning products (28%, 27%) and new carpet, dust, molds, smoke, and perfume (21%, 10%), which included dust from construction/renovation. Laboratory workers and technicians reported glutaraldehyde and formaldehyde (26%) and dental HCWs reported latex exposures (75%). The “other exposures” category accounted for 27% of all exposures (117/440), and reflects the broad range of products used in health care settings that may induce or exacerbate asthma. Some of the reported exposures were: nitrogen oxides, ethylene glycol, ethyl ether, laboratory animals, freon, isocyanates, pharmaceuticals, and pesticides.

The case classification for 305 confirmed HCW cases were compared to the 1,574 confirmed non-HCW cases. Proportionately more non-HCW cases were categorized as new-onset, with unknown inducer compared to HCW (45% vs. 38%) ($P \leq 0.01$). HCW were slightly more likely to be categorized as new onset with known inducer (30% vs. 27%), and more likely to be categorized as work-aggravated (23% vs. 18%). Ten percent of cases were identified as RADS in both groups.

During the interview, cases were asked several questions about their medical history including whether they had ever smoked and whether they had a history of allergies. Forty-five percent ($n = 136$) answered “yes” to the question, “Have you ever smoked cigarettes?” This may be compared to a population-based estimate of 48% (91.2 million people “ever smoked,” of 190.3 million people), in the 1995 National Health Interview Survey (CDC, 1997). More than one-third of the respondents ($n = 116$, 38%) reported having a history of allergies. Although not directly comparable, estimates of allergic rhinitis among the adult population range from 10% to 30% (AAAAI, 2002).

The HCWs were queried whether they were still exposed to the agents that triggered their asthma. In California,

TABLE III. Number and Percent Of Work-Related Asthma Cases Among Health Care Workers by Agent,* Reported by 10 or More Cases—California, Massachusetts, Michigan, and New Jersey, 1993–1997

Exposure	Number of cases	Percent (%)
Cleaning products	74	24
Latex	61	20
Indoor air pollution	37	12
Glutaraldehyde	27	9
Miscellaneous chemicals	27	9
Paints, solvents	21	7
Formaldehyde	15	5
Molds	14	5
Dust	14	5

*Each case may report up to three exposures; each case reported at least one exposure.

TABLE IV. Distribution of Exposures* Among Health Care Workers With Work-Related Asthma by Occupation[†]—California, Massachusetts, Michigan, and New Jersey, 1993–1997, n = 305

Occupation (number of cases)	Cleaning products	Latex	Glutaraldehyde and formaldehyde	Indoor air	Miscellaneous chemicals, paints/solvents, glues	New carpet, dust, molds, smoke, perfume	Other ^a exposures	Total exposures identified
Nurses ^b (123)	26	41	23	22	20	19	39	190
Office workers ^c (61)	17	2	3	6	19	13	22	82
Aides and therapists ^d (41)	11	8	3	3	12	4	17	58
Lab workers and technicians ^e (34)	4	1	9	2	2	8	17	43
Housekeeping and food prep ^f (19)	8	0	0	1	2	3	10	24
Dental health care workers ^g (12)	2	9	1	1	0	0	3	16
Other professional health care ^h (5)	3	0	1	1	0	1	2	8
Others ⁱ (10)	3	0	2	1	2	4	7	19
Totals (305)	74	61	42	37	57	52	117	440

*Up to three exposures may be coded for every case; each case reported at least one exposure.

[†]Occupation according to 1990 Census Occupation Code.

^aAmong other exposures are: Toluene, nitrogen oxides, ethylene glycol, ethyl ether, acrylate, laboratory animals, freon, isocyanates, pharmaceuticals, pesticides.

^bNurses include RNs (095) and LPNs (207).

^cOffice workers include administrators (014), managers (015, 022), psychologists (167), social workers (174), lawyers (178), health records technician (205), office supervisors (303), secretaries (313), stenographers (314), interviewers (316), receptionists (319), file, record, office and statistical clerks (335, 336, 379, 386), bookkeepers (337), billing clerks (339), telephone operators (348), bill collectors (378), administrative support (389), and welfare service aides (465).

^dAides and therapists include respiratory therapists (098), physical therapists (103), health aides (446), and nursing aides (447).

^eLab workers and technicians include chemists (073), clinical lab technologists (203), radiologic technicians (206), health technologist (208), biological technicians (223), science technicians (225), technicians, nec (235), and dental lab technicians (678).

^fHousekeeping and food prep include cooks (436), miscellaneous food prep (444), supervisors, cleaning and building services (448), maids and housemen (449), janitors (453), baggage porters (464), and laundry operators (748).

^gDental health care workers include dentists (085), dental hygienists (204), and dental assistants (445).

^hOther professional health care includes doctors (084), health diagnosing practitioners (089), and physician assistants (106).

ⁱOthers include inspectors (036), engineers (059), veterinarians (086), speech therapists (104), therapists nec (105), recreation workers (175), firefighting supervisors (413), photographic process operators (774), and miscellaneous machine operators (777).

Michigan, and Massachusetts, 43%, 28%, and 21%, respectively, of the cases (data not available from New Jersey) reported they were still exposed in the same facility to the identified agent(s). In some of the remaining cases, changes were made to reduce exposure, or transfer the affected worker to another area. In other cases, HCWs left employment. In Massachusetts, 20 workers reported they were fired or quit due to breathing problems; another 25 reportedly were still out of work on compensation at the time of the interview, for a total of 45 (48%) who were not at their usual jobs. In California, 35 (31%) reported they were fired, laid off, or stopped work on their physician's orders. In Michigan, 20 (28%) reported they were no longer working, among whom were three hospital workers who reported they were fired for "taking too much sick leave;" the sick leave was reportedly due to hospital stays and/or emergency room visits.

DISCUSSION

Surveillance findings from four states indicated that HCWs, a large and increasing worker population, are at risk for WRA. Sentinel surveillance offers opportunities for

prevention by identifying populations at risk and hazards. In addition, the workplace provides opportunities for health promotion. Wellness efforts have been more effective when integrated with improved workplace protection [Walsh et al., 1991; Sorenson et al., 1996, 2002]. The disproportionate number of cases among HCWs is consistent with reports from other countries [Provencher et al., 1997; Bena et al., 1999; Ross, 1999; McDonald et al., 2000; Esterhuizen et al., 2001; Hnizdo et al., 2001; Kopferschmitt-Kubler et al., 2002], and with the use in health care settings of well documented sensitizers and exposures to agents that cause or exacerbate asthma.

The SWORD (Surveillance of Work-related and Occupational Respiratory Disease) system in the UK found that the rate of occupational asthma in the health care industry was nearly 2.5 times the overall industry rate [Ross, 1999]. SWORD also identified latex as the fourth most common asthmagens and found a high incidence of occupational asthma in laboratory technicians, nurses, and radiographers [McDonald et al., 2000]. The SORDSA (Surveillance of work related and Occupational Respiratory Diseases programme in South Africa) system in South Africa identified

the largest number of WRA cases in the health care industry (16%) and found latex to be the most frequent exposure identified among cases (24%) [Esterhuizen et al., 2001; Hnizdo et al., 2001]. SORDSA identified occupational asthma among nurses, ICU workers, laboratory workers, and radiographers. The PriOR system in Italy found the largest number of cases and the third highest rate of WRA among HCWs [Bena et al., 1999]. The Observatoire National de Asthmes Professionnels, a voluntary reporting system for WRA in France, found that the rate of WRA among French HCWs was second only to bakers. Latex was the third most likely etiologic agent identified [Kopferschmitt-Kubler et al., 2002]. Karjalainen et al. [2001] found an increased relative risk for occupational asthma among medical and nursing workers in Finland compared to workers in administrative work. On the other hand, asthma among HCWs in Quebec was too infrequently reported to merit listing among the top seven industries noted from the PROPULSE system [Provencher et al., 1997].

Data from the National Center for Health Statistics' third National Health and Nutrition Examination Survey (NHANES) of the US population indicate that the hospital industry was associated with the highest estimated asthma prevalence for nonsmokers—14.4% (95% CI = 8.1–20.7) or more than twice the estimated asthma prevalence among non-smokers overall—6.6% (95% CI = 5.8–7.4) [NIOSH, 1999b]. The NHANES Survey did not assess work-relatedness of individual cases.

Strengths and Limitations of the Data

SENSOR data cannot provide estimates of the true incidence or prevalence of WRA. Although all four states have mandatory reporting laws, WRA is both under-diagnosed and under-reported by physicians. In some cases the symptoms of asthma are not diagnosed [Deprez et al., 2002], while in others, the links to work are not made [Milton et al., 1998]. Other methods and analyses have provided better estimates of WRA incidence rates and population attributable risk [Milton et al., 1998; Henneberger et al., 1999; Bakke and Gulsvik, 2000; Karjalainen et al., 2001; Arif et al., 2002; Mannino et al., 2002].

The apparent disproportion of cases among HCWs may reflect differential diagnosis, reporting, and case confirmation among this workforce. Employees in health care probably have greater access to care and information about illness than non-HCWs. Among the 305 cases reported in the four states, 63% worked in hospitals with potential access to employee health services. In addition, approximately half were categorized as nurses, physicians, therapists, or aides, all of whom have received education about health-related issues. This factor probably increases the number of workers who recognize asthma symptoms and seek care and may contribute to the higher proportion of HCWs with work-

aggravated asthma (23% vs. 18%). In addition, HCWs with new-onset WRA were more likely to have a known inducer identified than non-HCWs with new-onset WRA ($P = 0.06$), which may result from physicians' familiarity with some of the asthma inducers in their own work settings, such as latex gloves. While heightened knowledge of disease and exposures may increase the prevalence of confirmed WRA among HCWs, even with an informed work force, over half of the 206 HCW with new-onset WRA (excluding RADS) did not report a known inducer.

Also, HCWs may be more likely to respond to telephone interviews and be counted among confirmed cases. In California and Massachusetts, but not Michigan and New Jersey, case confirmation relied solely on completion of telephone interviews. Interviews were more likely to be completed by women, non-Hispanics, and professionals compared to men, Hispanics, and workers in manufacturing or construction. This differential case confirmation did not account for the whole difference in California and Massachusetts (results not presented), and data from Michigan and New Jersey were not limited in the same way.

HCWs were significantly more likely to file for and receive workers' compensation for their WRA than non-HCWs. Many eligible workers do not file for compensation, and some of the disincentives may affect non-HCWs more than HCWs [Biddle et al., 1998; Rosenman et al., 2000; Azaroff et al., 2002; Shannon and Lowe, 2002]. Factors associated with filing for workers compensation in these studies included female gender, union membership, non-immigrant status, increased length of employment, and not being self-employed. Among the factors that may contribute to HCWs' greater success in being awarded workers compensation are race and professional status of many of the claimants, and the increased proportion of known inducers.

Agents Identified by Health Care Workers

The following section describes the agents most commonly reported by HCWs. Workers with asthma will have a better prognosis if triggers are identified and controlled in their workplaces. Additional information about the selection and use of safer alternatives to hazardous chemicals in the hospital industry may be found at the Sustainable Hospitals website <http://www.sustainablehospitals.org/>.

Cleaning Products

Cleaning products, the predominant agent reported by cases ($n = 74$, 24%) in this industry, included disinfectants as well as cleaners. Quaternary ammonium compounds (e.g., benzalkonium chloride, n-alkyl dimethyl benzyl ammonium chloride, lauryl dimethyl benzyl ammonium chloride), called "quats," are commonly used disinfectants for surface clean-

ing in clinical and food preparation areas and are regulated by the US EPA as antimicrobial pesticides. Sensitization to several quaternary ammonium compounds has been documented [Bernstein et al., 1994; Burge and Richardson, 1994; Purohit et al., 2000] two of these compounds are recognized asthmagens. Cleaning products also contain many irritant chemicals, e.g., bleach, ammonia, hydrochloric acid. In a study from the same four states, cleaning products were associated with 12% of cases across all industries and occupations [Rosenman et al., 2003]

Natural Rubber Latex

Latex was the second most commonly reported exposure. Seventy-three percent of all dental worker cases and 35% of all cases who were nurses identified latex. Latex allergy has been attributed to latex protein exposure from frequent glove changes, especially in operating rooms and emergency departments, and dermal and airborne exposure [Turjanmaa et al., 1988; Berky et al., 1992; Hamann, 1993; Holzman, 1993; Swanson et al., 1994; Kelly et al., 1996; OSHA, 1999]. NIOSH [1997] issued an Alert on latex and OSHA issued a Technical Information Bulletin on latex in 1999. Adverse reactions range from localized dermatitis to anaphylaxis, including WRA. The huge increase in use of latex gloves in the 1980s, in response to requirements for universal precautions, led to shortcuts in glove manufacturing that increased the availability of latex protein. Replacing latex materials with synthetics, banning latex balloons and careful purchasing policies can reduce latex exposures.

Indoor Air Quality

Indoor air quality issues in health care are similar to those in other non-industrial workplaces. Reported exposures in these data (paints/solvents, glues, carpet, dust, mold, and miscellaneous chemicals) included bystander exposures from construction or maintenance activities. Inadequate ventilation, coupled with widespread chemical use, may be responsible [Behling and Guy, 1993].

Mold exposures were reported by 5% ($n = 14$) of cases. Some specific molds have been identified as asthma inducers [Hunting and McDonald, 1995; ACOEM, 2002; Zureik et al., 2002]. Recent European research reported an association between mold sensitization and severity of asthma [Zureik et al., 2002]. Preventing moisture incursion, careful facility and ventilation system maintenance, and control of air contaminants from construction/renovation, can prevent exposure to mold and ameliorate other indoor air quality hazards.

Glutaraldehyde

Glutaraldehyde, identified by 9% ($n = 27$) of cases, is an effective broad-spectrum anti-microbial agent, commonly

used in health care facilities as a cold sterilizing agent for medical, dental, and surgical instruments, particularly endoscopes and plastic materials. It is also an ingredient in X-ray developer [Byrns et al., 2000] and is used as a tissue fixative in pathology laboratories. It is a strong irritant to the skin, eyes, and respiratory system and has been reported to cause asthma [Chan-Yeung et al., 1993; Gannon et al., 1995; DiStefano et al., 1998]. Two recent articles document new-onset asthma and respiratory symptoms among radiographers exposed to X-ray processing chemicals [Dimich-Ward et al., 2003; Liss et al., 2003]. There are alternatives to glutaraldehyde for disinfection, including peracetic acid, hydrogen peroxide and ortho-phthalaldehyde. Glutaraldehyde is still used, although special precautions, adequate ventilation, and employee training are recommended. A NIOSH [2001] pamphlet about glutaraldehyde is available, online and in print.

Formaldehyde

Formaldehyde (5% of cases) is a colorless, flammable gas with a strong, pungent, irritating odor. It is used in health care as a tissue preservative and disinfectant, especially in dialysis units. Commercially, formaldehyde is sold as formalin (usually stabilized with methanol) in a water solution of various strengths; it is also available as a solid (para-formaldehyde). Formaldehyde may also off-gas from building materials, such as plywood, particleboard and some fabrics. Formaldehyde has been recognized as an asthmagen in residential and workplace settings [Burge et al., 1985; Lemiere et al., 1995; Norback et al., 1995]; OSHA [1992] has recognized formaldehyde as a pulmonary sensitizer and carcinogen. Exposure must be minimized with engineering controls.

CONCLUSION

Four state-based surveillance systems for WRA documented that HCWs are at risk for WRA. Despite demographic and employment pattern variations across the four states, health care emerged as the first or second most frequently reported industry among all cases of WRA reported from 1993 to 1997, and in proportions exceeding their workforce representation. Because of the size and projected growth of this industry, the lessons from these surveillance data are important in reducing the burden of asthma in the US population and reducing risk factors for hundreds of thousands employed in health care.

Exposures to several of the asthma triggers identified by HCWs may be reduced, and even eliminated, from health care services by replacement with safer substitutes. To further minimize the risk, engineering controls and safe work practices are needed. Exposures may be reduced or prevented by better planning and control of construction and renovation

projects, and adequate facility maintenance to prevent inadvertent moisture incursion and mold growth. Purchasing decisions and planning should take into consideration cleaning products, disinfectants, construction materials, and gloves that have been tested for their allergenic and irritant properties.

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APPENDIX

CASE REPORTS

Four case reports are provided to demonstrate the range of agents, occupations and circumstances of exposure represented in the data. The case reports also demonstrate the limited information that may be available regarding each case.

Case Report #1, California

A 45-year-old, non-smoking, female X-ray technician sought emergency medical treatment for throat irritation, cough, chest tightness, shortness of breath, sinus congestion and hives which began within 5 min after X-ray developing tanks overflowed at work. She reported no ventilation in the room where she worked. She was treated with inhaled albuterol and oral diphenhydramine hydrochloride. She returned to the emergency room five times over the next 5 days for breathing treatments, and missed work for 7 days after the incident. She reported that her asthma symptoms continued over the following 10 months and that many different substances triggered her symptoms. (This case was classified as RADS.) She still worked in the same job, but felt her exposure had been lessened through engineering controls,

including addition of a wall and ventilation. Among 10 workers with similar exposures in her workplace, she knew of two others with breathing problems.

Note: No information was available about specific exposures. X-ray developing fluids may contain glutaraldehyde and other respiratory irritants, e.g., acetic acid, potassium hydroxide, hydroquinone. X-ray processing may also release sulfur dioxide [Byrns et al., 2000].

Case Report #2, Michigan

After working at a hospital for 10 years, a male in his 40s started a 3-month rotation as a radiation therapist in the Simulation Room for the hospital's cancer center. He developed WRA from exposure to methylene bisphenyl diisocyanate (MDI), which was used to create foam immobilization cradles for radiation oncology patients. His duties included pouring a two-part MDI-containing mixture into a plastic bag, sealing it, then molding the bag to fit the patient. He wore latex gloves, a gown and sometimes a surgical mask while doing this job in a small, poorly ventilated room.

He developed sneezing, headaches and sinus problems, along with chest tightness and slight cough, but did not notice shortness of breath or wheezing. He did not have a history of asthma or allergies. He had smoked approximately a pack of

cigarettes a day for 2 years in his teens. His breathing tests were within normal limits but he had a positive methacholine challenge test. He was given an albuterol inhaler that he used periodically. Although he stopped working in the Simulation Room pursuant to his doctor's recommendation, his intermittent chest symptoms did not resolve completely until 5 months later.

A Michigan OSHA enforcement inspection was conducted in the Simulation Room, which included querying co-workers about breathing problems. Air concentrations of MDI were below the level of detection. The inspection revealed that many employees working in the Simulation Room had no knowledge or training about MDI, including the inadequacy of surgical masks. The industrial hygienist noted that latex gloves worn by the radiation therapists were not protective against isocyanates [NIOSH, 1999a], and recommended butyl, nitrile, or neoprene gloves. Among the nine co-workers interviewed, one had developed asthma and one other radiation therapist had developed breathing problems consistent with asthma since working with MDI. A medical surveillance program for workers in the area with potential exposure to MDI was recommended.

Case Report #3, Massachusetts

A 42-year-old, non-smoking, female worked as an assistant nurse manager/registered nurse in the gynecology/oncology department at a large urban hospital. She had been employed at this hospital for over 6 years when she began to notice respiratory symptoms associated with work. She reported wheezing, cough, chest tightness and shortness of breath, which were diagnosed as WRA, and was hospitalized once for her asthma. She had been diagnosed previously with asthma when she was 3-year-old, with allergies to trees, grass, dust, dogs and molds, but had been free of symptoms since she was 24 years old. Her work-related symptoms were triggered by the use of powdered latex gloves; she further

reported problems with the ventilation system. She was out of work nearly 2 years after her diagnosis and had been awarded workers' compensation.

The hospital assessed latex in the environment and implemented changes to minimize exposures, replacing latex gloves with non-latex gloves and low allergen, non-powdered gloves, banning latex balloons, and correcting problems in the ventilation system. Further, the hospital administration developed a Latex Committee in collaboration with the hospital unions to provide oversight on latex use.

Case Report #4, New Jersey

A 52-year-old, non-smoking female worked for 9 years in the pulmonary function testing department of an ambulatory care facility. During that time she suffered recurrent symptoms of cough, shortness of breath, wheezing, and chest tightness, as well as episodes of sinusitis and bronchitis. Symptoms improved on weekends and resolved completely while on vacations. An evaluation of the facility revealed that the affected individual and other employees were found to be exposed to glutaraldehyde vapors released from a bucket of sterilizing solution stored in a cabinet. Her job required that she immerse certain pieces of equipment into the bucket of solution for 1 hr, then remove and rinse the equipment in water until "the smell of glutaraldehyde is gone." No ventilation system controlled the release of glutaraldehyde into the air and the odor was detectable in the workroom and adjacent hallway. Evidence of splashes and spills were visible around the bucket under the cabinet. She avoided work with glutaraldehyde for several months at the urging of her personal physician, and symptoms resolved. However, when she was required to sterilize some equipment on one occasion, symptoms returned. The bucket of glutaraldehyde has since been removed and equipment is now sent out of the department for gas sterilization. Her symptoms improved significantly.