Deaths Due to Bloodborne Infections and Their Sequelae Among Health-Care Workers

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Background *The odds of dying from bloodborne infections among health-care workers has not been well studied.*

Methods *Using data from the National Occupational Mortality Surveillance (NOMS) system, a matched case-control design was employed to examine the relationship between health-care employment and death from HIV, hepatitis B (HBV), hepatitis C (HCV; non-A/non-B viral hepatitis), liver cancer, and cirrhosis from 1984 to 2004. We examined the whole health-care industry and specific health-care occupations.*

Results *From 1984 to 2004, NOMS captured 248,550 deaths from bloodborne pathogens and their sequelae. Employment in the health-care industry was associated with increased risk of death from HIV (MOR = 2.27; 95% confidence interval [CI] = 2.11–2.44), HBV (MOR = 1.98; CI = 1.58–2.48), and cirrhosis (MOR = 1.09; CI = 1.04–1.15) among males, and death from HCV among both males (MOR = 1.46; CI = 1.22–1.75) and females (MOR = 1.22; CI = 1.05–1.40). Nursing was the occupation with the highest MORs among males for HIV and HBV, but female nurses were at decreased risk of dying from HIV (MOR = 0.69; CI = 0.57–0.83).*

Conclusions *Employment in the health-care industry was found to be associated with deaths from several bloodborne pathogens and their sequelae among males, but only with HCV among females from 1984 to 2004 in this exploratory study.* Am. J. Ind. Med. 51:812–824, 2008. *Published 2008 Wiley-Liss, Inc.*[†]

KEY WORDS: health personnel; blood-borne pathogens; HIV; hepatitis viral human; liver cirrhosis

INTRODUCTION

Health care is one of the largest industries in the United States, employing over 14 million workers in 2006 [Bureau of Labor Statistics—BLS, 2007]. Although there is clear evidence that health-care workers are frequently exposed to infectious body fluids via needlesticks and other occupational accidents [National Institute for Occupational Safety and Health—NIOSH, 2001; Panlilio et al., 2004] and some cases of resulting infections have been well documented, health-care workers are also at risk of acquiring bloodborne infections through non-occupational routes. Little direct evidence is available on the risk of dying due to bloodborne infections among health-care workers or the odds of dying from these infections among health-care workers compared to other workers. Although deaths from AIDS among health-care workers have been reported, we are not aware of any previous studies that examine deaths from hepatitis B virus (HBV), hepatitis C virus (HCV), or their sequelae (chronic liver diseases) among health-care workers.

Data on the incidence of HIV infection and AIDS among health-care workers have been collected by the Centers for Disease Control and Prevention (CDC) through the HIV/AIDS Reporting System and the National Surveillance for Occupationally Acquired HIV Infection system [Chamberland et al., 1991; Do et al., 2003; CDC, 2006b]. Between

1985 and 2002, the CDC received reports of 24,844 health-care workers with AIDS, but only 57 health-care workers (26 of whom have developed AIDS) have been documented to have acquired HIV occupationally, and only 139 additional cases of HIV in U.S. health-care workers are considered to be possibly occupationally acquired. Of all 24,844 reported health-care workers with AIDS (including non-occupationally acquired cases) as of December, 2002, 73% had died. Health-care workers with AIDS who report non-occupational risk factors (e.g., male homosexual-bisexual contact or IV drug use) are assumed to not have acquired their infections occupationally.

CDC estimated an incidence of 17,000 HBV infections per year among health-care workers in 1983, which declined to approximately 400 in 1995, after widespread immunization of health-care workers and adoption of the OSHA bloodborne pathogens standard [Mahoney et al., 1997; Occupational Safety and Health Administration—OSHA, 2006]. The CDC estimates that 87 acute cases of HBV attributable to occupational exposure occurred in 2004 (personal communication with Annemarie Wasley, Division of Viral Hepatitis, CDC, April 20, 2007). An estimated 50–150 transmissions of HCV also occur among health-care workers annually, but seroprevalence studies of HCV in health-care workers suggest these workers have minimally increased risk for HCV compared with the general population [CDC, 2001; Henderson, 2003; Sepkowitz and Eisenberg, 2005].

No data are available to link deaths due to HBV or HCV among health-care workers to specific occupational exposures. Health-care workers infected with HBV or HCV may also die of chronic liver disease, such as carcinoma of the liver or cirrhosis, which may not be recognized as being caused by infection. The goal of this study was to assess whether data from the U.S. National Occupational Mortality Surveillance (NOMS) system indicate that health-care workers are more likely than other workers to die from bloodborne pathogens and their sequelae.

NOMS is a collaborative effort between the National Institute for Occupational Safety and Health (NIOSH), the National Center for Health Statistics, the National Cancer Institute, and selected state health departments. It augments the mortality vital statistics system with coded industry and occupation data. NIOSH has made data from the NOMS system (1984–1998) available on the Web in the form of a query system for access to precalculated proportional mortality ratios (PMRs) by occupation or industry (http://dshefs.niosh.cdc.gov/noms/default.html). After noting that PMRs for HIV and viral hepatitis were elevated among male health-care workers, we conducted the present case-control study to further explore the odds of death due to these diseases among health-care workers using a different methodology and more years of data. This report uses NOMS data from 1984 to 1999 and 2003 to 2004. (No data is available for the period from 2000 to 2002.) Specifically, we used a matched case-control design to investigate the crude association between employment in the health-care industry and deaths from specific infections and their sequelae. We did not have data linking deaths in NOMS to specific occupational exposures or to non-occupational risk factors.

METHODS

Death certificate data contained in the NOMS database were used. Between 1984 and 1999, 28 states submitted data for 2 or more years. Ten states also submitted data for the years 2003 and 2004, but only eight of these states met quality control standards for inclusion in this analysis. Usual occupation and industry of the decedent are coded by states according to the 1990 Census Bureau Occupation Codes (COC) and Census Bureau Industry Codes (CIC), and underlying and contributing causes of death are coded according to the 9th (1984–1998) or 10th (1999, 2003–2004) Revision of the International Classification of Diseases (ICD-9 or ICD-10) [World Health Organization—WHO, 1977, 1992]. This database has previously been used in a case-control study to evaluate occupational silica exposure and risk of various diseases [Calvert et al., 2003]. The National Center for Health Statistics (NCHS) provided the surveillance data to NIOSH without personal identifiers, thus exempting this work from evaluation by the human subjects review board.

Deaths from each of the diseases of interest were analyzed separately. The diseases of interest included: HIV/AIDS (ICD-9 042-044; ICD-10 B20-B24), HBV (ICD-9 0702, 0703; ICD-10 B16, B18.0, B18.1), non-A/non-B hepatitis/HCV (ICD-9 0704-0709; ICD-10 B17.1, B18.2), carcinoma of the liver (ICD-9 155; ICD-10 C22), and chronic liver disease/cirrhosis (ICD-9 571, 5721-5728; ICD-10 K73, K74).

A separate control group was selected for each of the diseases of interest. Controls were selected from among subjects whose death certificates did not mention any of the diseases of interest. For the analyses of carcinoma of the liver and chronic liver disease/cirrhosis, death certificates mentioning alcohol-related causes of death (ICD-9 291, 303, 3050, 3575, 4255, 5353, 7903, 5710-5713, 8600, 8601; ICD-10 F10, G62.1, G31.2, G72.1, I42.6, K29.2, K70, K86.0, X45, Y15, T51.0, T51.1, T51.9, X65, R78.0) were also excluded from being controls. For each disease of interest except for HIV/AIDS, three controls were matched to each case. The pool of eligible controls was smaller for subjects dying of HIV/AIDS because many of those who died of HIV/AIDS were young and the overall mortality at this age is low; therefore, only one control was matched to each HIV/AIDS case in order to maximize the number of cases included in the analysis. Death certificates listing occupation or industry as retiree, homemaker, or unemployed, and those with no occupation and industry listed were excluded from being cases or controls.

Cases and controls had to be at least 18 years of age. Subjects who were neither Caucasian nor African-American were excluded because of small numbers. We excluded deaths among non-paid workers (e.g., homemakers) and persons with incomplete or missing industry and occupation data from both case and control groups because we wanted to focus on occupational risk factors. The number of death certificates excluded from all analyses, and the reasons for the exclusions are shown in Table I. Controls were matched to each case based on sex, race, state of residence, 5-year age group, and year of death group. These factors are associated with the outcomes, but not amenable to intervention. Matching was used in the study design, rather than statistical control in the analysis, in order to increase the precision of comparisons by balancing the number of cases and controls at each level of these confounders.

Four groups were identified as the exposed. These included all persons employed in the health care industry (CIC 812-840 (Health Services) listed as usual industry on death certificate) and three occupational subsets with high risk of bloodborne pathogen exposure: physicians (COC 084); registered nurses (RNs, COC 095) and licensed practical nurses (LPNs, COC 207); and clinical laboratory technologists and technicians (laboratory technicians; COC 362 with CIC 812-840).

Analysis of Data

Using SAS Version 9.1 [SAS Institute, 2003], mortality odds ratios (MORs) were estimated by conditional logistic regression using the PROC PHREG procedure, and 95% confidence intervals were estimated using the Wald test. We estimated MORs separately for males and females because the prevalence of non-occupational risk factors was expected to vary by sex. We also estimated MORs separately for Caucasians and African-Americans, but only race-specific MORs that differed from the combined-race MORs are reported. Marital status at death was included in the models as a proxy for sexual risk behaviors [Cowan et al., 1990; Biggar and Melbye, 1996]. Marital status was classified as

TABLE I. Number of Death Certificates Excluded From All Analyses, and the Reason for the Exclusions

Reason for exclusion	Number (% of total records available)
Race not Caucasian or African-American	79,314 (0.77)
Age (<18 years or >119)	5 (0.00)
Occupation and/or industry = retiree, homemaker, unemployed, or no occupation and industry was listed	3,043,561 (29.55)
Total excluded	3,122,880 (30.32)

Total number of death certificates available = 10,299,984.

married at the time of death, formerly married (divorced or widowed at the time of death), or never married. Marital status information was available for 94.5–98.9% of records, depending on disease of interest.

Separate MORs for each disease were estimated overall and for each of three time periods: 1984–1991, 1992–1999, and 2003–2004. We hypothesized that the risk of dying from bloodborne pathogens and their sequelae was different between these time periods because of changing OSHA standards, and availability of vaccine in the case of HBV. We tested for significant differences between MORs by dividing the difference between time period-specific regression coefficients by the standard error of the difference, and assumed that the ratio was distributed as a standard normal variable.

RESULTS

In total, 73,084 deaths due to bloodborne pathogens (HIV, HBV, and HCV) and 175,466 deaths due to liver cancer or cirrhosis were recorded in NOMS between 1984 and 2004.

HIV/AIDS

The NOMS database included 54,789 deaths from HIV among males, which were matched to 54,677 controls, and 7,324 deaths from HIV among females, which were matched to 7,320 controls. A majority of these deaths occurred between 1992 and 1999. From the first time period (1984–1991) to the last time period studied (2003–2004), the mean age at death increased (Table II).

Among males, employment in the health-care industry was associated with death from HIV in the first two time periods, with the strength of the association decreasing with time. The observed association was highest among male nurses compared to male physicians or laboratory technicians in the first two time periods (Table III).

Among all females, employment in the health-care industry was not significantly associated with increased risk of death from HIV. However, when African-American females were analyzed separately, employment in the health-care industry was significantly associated with increased risk of death from HIV between 1984 and 1991 with an MOR of 1.30 (95% CI 1.01–1.67; data not shown). Among females, health-care occupations, especially nursing, appear to have been negatively associated with death from HIV between 1992 and 1999; this negative association held true for both Caucasian and African-American female nurses when they were analyzed separately (data not shown).

HBV

The NOMS database included 3,021 deaths from HBV among males, which were matched to 9,061 controls, and 706

deaths from HBV among females, which were matched to 2,116 controls (Table II).

Among males, employment in the health-care industry was associated with death from HBV in the first two time periods. Male nurses had the highest risk of death from HBV, with HBV among male nurses in the first time period (1984–1991) yielding the highest MOR (16.28) of this study (Table III).

Among females, employment in the health-care industry was not significantly associated with death from HBV, except among laboratory technicians, which yielded an MOR for all years combined of 4.30 (95% CI 1.52–12.14).

HCV (Non-A/Non-B Hepatitis)

The NOMS database included 5,405 deaths from HCV (non-A/non-B hepatitis) among males, which were matched to 16,221 controls, and 1,839 deaths from HCV (non-A/non-B hepatitis) among females, which were matched to 5,504 controls. More of these deaths occurred between 1992 and 1999 than in any other time period (Table II).

Among both males and females, employment in the health-care industry was significantly associated with death from HCV (non-A/non-B hepatitis) between 1992 and 1999 and in all years combined. This association was strongest among male nurses between 1992 and 1999 and among male laboratory technicians in all years combined (Table III).

Carcinoma of the Liver and Cirrhosis

The NOMS database included 22,944 deaths from carcinoma of the liver and 102,197 deaths from cirrhosis without contributing alcohol-related causes among males, which were matched to 68,832 and 306,567 controls, respectively. The database included 8,586 deaths from carcinoma of the liver and 41,739 deaths from cirrhosis without contributing alcohol-related causes among females, which were matched to 25,749 and 125,169 controls, respectively (Table II).

Among males, employment in the health-care industry was significantly associated with death from cirrhosis in 1984–1991 and 1992–1999 and death from liver carcinoma in 1992–1999 (Table III). These associations do not appear to be substantially different among the different health-care occupations studied.

Among females, employment in the health-care industry was not significantly associated with increased risk of death from either carcinoma of the liver or cirrhosis (Table III). Between 1992 and 1999 employment as a health-care worker, especially as a nurse, was found to be negatively associated with death from liver carcinoma among females.

DISCUSSION

Of the 248,550 eligible deaths from bloodborne pathogens and their sequelae recorded in NOMS, 6.12% occurred among workers whose death certificate reported the health-care industry as their usual industry of employment. Employment in the health-care industry was found to be associated with deaths from several of the diseases of interest among males, but only with HCV among females in this exploratory study. HIV accounted for the largest number of deaths among the bloodborne pathogens; 4,806 (7.74%) HIV deaths occurred among health-care workers.

In comparison, 24,844 cases of AIDS, including 18,136 deaths, among health-care workers in the entire United States had been reported to the National Center for Infectious Disease as of December 2002, which represented 5.1% of the total AIDS cases reported with occupational information [CDC, 2006b]. This number is higher than the number in NOMS because it includes deaths from all 50 states for each year through 2002.

At least three relevant PMR studies using NOMS data have been published. Burnett et al. [1997] reported the industries with the highest PMRs for HIV between 1984 and 1988, which included beauty shops (white males), colleges and universities (black males), and unspecified manufacturing (black females). Except for possibly beauty shops, these industries are not thought to have occupational exposure to bloodborne pathogens, so they may be surrogates for non-occupational risk factors. Mortality patterns among two specific groups of health-care workers—female nurses and all physicians—according to PMRs calculated from NOMS data have also been reported. Peipins et al. [1997] found elevated PMRs for viral hepatitis among working-age nurses compared to all workers (PMR = 175) and white-collar workers (PMR = 171), but did not find excess deaths for HIV among nurses from 1984 to 1990. Frank et al. [2000] found an elevated PMR for hepatitis (excluding chronic nonviral; PMR = 178), but low PMRs for all liver disease (PMR = 80) and HIV/AIDS (PMR = 83) for white male physicians compared with all white male professionals from 1984 to 1995.

Our findings in this case-control study are consistent with the proportional mortality ratios (PMRs) by occupation and industry available through the NOMS web page (http://dshefs.niosh.cdc.gov/noms/default.html). Specifically, PMRs for HIV and viral hepatitis are elevated among male health-care workers (e.g., PMR = 236 for HIV among white males, 166 for HIV among black males, and 233 for HBV among white males), but not among female health-care workers.

Employment in the health-care industry, especially in occupations involving direct contact with patients and body fluids (i.e., nurses, physicians, laboratory technicians), can be considered a surrogate for occupational exposure to blood-

TABLE II. Deaths Due to Bloodborne Infections and Their Sequelae Among Health Care Workers

Disease	Case/control	Total deaths	Health-care worker (%)	Physician (%)	Nurse (%)	Laboratory technicians (%)	Married at death (%)	Mean age at death (years)	Caucasian (%)
HIV									
HIV in time period 1 (1984–1991)									
Males	Cases	19,064	6.34	0.35	1.11	0.31	15.99	38.67	68.90
	Controls	19,032	2.65	0.23	0.20	0.15	52.17		
Females	Cases	1,720	16.28	0.17	4.01	0.29	26.06	38.64	37.79
	Controls	1,720	15.87	0.17	4.30	0.41	44.08		
HIV in time period 2 (1992–1999)									
Males	Cases	35,163	6.51	0.26	1.03	0.34	16.26	40.25	58.36
	Controls	35,081	2.80	0.21	0.22	0.13	46.04		
Females	Cases	5,535	17.38	0.09	2.55	0.36	24.23	40.05	26.73
	Controls	5,533	18.40	0.18	4.52	0.54	40.84		
HIV in time period 3 (2003–2004)									
Males	Cases	562	5.34	a	0.71	0.18	13.19	45.58	71.94
	Controls	564	2.66		0.53	0.18	45.10		
Females	Cases	69	17.39	a	4.35	0	18.84	44.89	41.91
	Controls	67	14.93		5.97	1.49	31.34		
HIV in all years combined									
Males	Cases	54,789	6.44	0.29	1.06	0.33	16.14	39.76	62.17
	Controls	54,677	2.74	0.21	0.22	0.13	48.06		
Females	Cases	7,324	17.46	0.10	2.91	0.34	24.58	39.76	29.47
	Controls	7,320	17.77	0.18	4.48	0.52	41.47		
HBV									
HBV in time period 1 (1984–1991)									
Males	Cases	1,279	4.22	0.86	1.09	0.23	52.33	55.22	82.96
	Controls	3,837	2.32	0.60	0.05	0.05	65.07		
Females	Cases	312	18.59	0.32	5.77	1.60	37.92	59.15	79.49
	Controls	936	14.96	0.11	5.56	0.11	38.50		
HBV in time period 2 (1992–1999)									
Males	Cases	1,652	5.57	0.85	0.85	0.36	41.31	52.56	78.27
	Controls	4,956	2.38	0.28	0.12	0.12	56.62		
Females	Cases	372	17.74	0.54	6.99	1.34	31.45	60.02	65.86
	Controls	1,116	16.04	0	6.36	0.45	37.56		
HBV in time period 3 (2003–2004)									
Males	Cases	90	6.67	1.11	0	a	41.11	55.36	86.31
	Controls	268	2.99	0.37	1.12		56.82		
Females	Cases	22	4.55	0	0	a	27.27	59.06	95.35
	Controls	64	17.19	1.56	9.38		33.33		

Table (rotated). Column headers are not printed; section labels appear inline. Values for the two rightmost columns are given once per sex group and are shown on the Cases row.

Sex	Status	N							
HBV in all years combined									
Males	Cases	3,021	5.03	0.86	0.93	0.30	45.76	53.77	80.49
	Controls	9,061	2.37	0.42	0.12	0.09	60.09		
Females	Cases	706	17.71	0.42	6.23	1.42	34.10	59.61	72.79
	Controls	2,116	15.60	0.09	6.10	0.28	37.84		
HCV									
HCV in time period 1 (1984–1991)									
Males	Cases	743	3.77	0.94	0.13	0.40	68.65	61.31	87.62
	Controls	2,229	2.38	0.54	0.04	0.09	67.32		
Females	Cases	339	17.11	0	8.26	0	41.42	60.48	80.83
	Controls	1,017	14.26	0.10	5.01	0.39	41.24		
HCV in time period 2 (1992–1999)									
Males	Cases	3,943	3.53	0.38	0.36	0.18	54.88	54.86	82.00
	Controls	11,826	2.27	0.30	0.11	0.08	58.67		
Females	Cases	1,326	18.10	0.08	5.81	0.53	34.19	61.13	77.44
	Controls	3,975	15.17	0.08	5.41	0.45	39.25		
HCV in time period 3 (2003–2004)									
Males	Cases	719	2.78	0.28	0.56	0.14	44.92	54.69	89.43
	Controls	2,166	2.54	0.18	0.55	0.09	53.54		
Females	Cases	174	21.84	0	6.32	1.15	31.61	57.02	86.59
	Controls	512	22.46	0.39	7.81	0.20	44.62		
HCV in all years combined									
Males	Cases	5,405	3.46	0.44	0.35	0.20	55.27	55.72	83.76
	Controls	16,221	2.32	0.32	0.16	0.08	59.11		
Females	Cases	1,839	18.27	0.05	6.31	0.49	35.18	60.62	78.92
	Controls	5,504	15.68	0.11	5.56	0.42	40.11		
Liver cancer									
Liver cancer in time period 1 (1984–1991)									
Males	Cases	10,477	1.99	0.46	0.06	0.02	71.18	68.55	88.54
	Controls	31,431	1.82	0.35	0.06	0.04	68.59		
Females	Cases	3,779	12.62	0.11	5.40	0.24	36.38	69.75	86.32
	Controls	11,337	12.35	0.04	5.42	0.19	32.57		
Liver cancer in time period 2 (1992–1999)									
Males	Cases	11,422	2.19	0.49	0.06	0.07	69.82	68.67	88.60
	Controls	34,259	1.85	0.37	0.06	0.03	65.90		
Females	Cases	4,451	12.56	0.13	4.63	0.18	34.63	70.85	86.27
	Controls	13,340	13.93	0.10	5.40	0.28	32.15		
Liver cancer in time period 3 (2003–2004)									
Males	Cases	1,045	1.82	0.38	0.10	0	66.22	67.41	92.93
	Controls	3,142	2.32	0.45	0.16	0.10	60.34		

(Continued)

TABLE II. (*Continued*)

Disease	Case/control	Total deaths	Health-care worker (%)	Physician (%)	Nurse (%)	Laboratory technicians (%)	Married at death (%)	Mean age at death (years)	Caucasian (%)
Females	Cases	356	13.48	0	3.96	0.56	34.83	71.00	92.93
	Controls	1,072	17.35	0.19	6.81	0.19	34.58		
				Liver cancer in all years combined					
Males	Cases	22,944	2.08	0.47	0.06	0.04	70.24	68.56	88.77
	Controls	68,832	1.86	0.36	0.06	0.04	66.81		
Females	Cases	8,586	12.63	0.12	4.94	0.22	35.37	70.37	86.57
	Controls	25,749	13.38	0.07	5.47	0.24	32.43		
Cirrhosis									
				Cirrhosis in time period 1 (1984–1991)					
Males	Cases	56,722	2.04	0.43	0.07	0.06	65.11	64.43	90.28
	Controls	170,154	1.88	0.37	0.08	0.04	69.32		
Females	Cases	21,889	13.46	0.12	5.73	0.32	41.01	65.40	86.96
	Controls	65,658	13.26	0.09	5.60	0.26	38.80		
				Cirrhosis in time period 2 (1992–1999)					
Males	Cases	42,267	2.21	0.37	0.12	0.07	60.12	63.89	88.61
	Controls	126,781	2.03	0.38	0.10	0.05	64.85		
Females	Cases	18,536	14.68	0.09	5.42	0.33	38.16	66.33	85.57
	Controls	55,593	14.44	0.08	5.31	0.28	36.83		
				Cirrhosis in time period 3 (2003–2004)					
Males	Cases	3,208	2.15	0.22	0.22	0.03	54.82	63.02	93.91
	Controls	9,632	2.17	0.38	0.13	0.12	58.64		
Females	Cases	1,314	17.35	0.08	5.18	0.46	39.65	65.77	94.92
	Controls	3,918	17.56	0.18	6.20	0.26	38.61		
				Cirrhosis in all years combined					
Males	Cases	102,197	2.11	0.40	0.10	0.06	62.58	64.16	89.70
	Controls	306,567	1.95	0.37	0.09	0.05	67.00		
Females	Cases	41,739	14.13	0.11	5.58	0.33	39.62	65.83	86.59
	Controls	125,169	13.92	0.09	5.49	0.27	37.87		

States participating in NOMS.

1984–1991: Alaska, Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Utah, Vermont, Washington, West Virginia, Wisconsin.

1992–1999: Colorado, Georgia, Hawaii, Idaho, Indiana, Kansas, Kentucky, Maine, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Rhode Island, South Carolina, Utah, Vermont, Washington, West Virginia, Wisconsin.

2003–2004: Hawaii, Idaho, Indiana, Kansas, Kentucky, Nevada, Utah, West Virginia.

[a]Undefined; no exposed cases or controls.

TABLE III. Conditional Logistic Regression Results for Deaths Due to Bloodborne Pathogens and Their Sequelae Among Health-Care Workers Compared to Other Workers, Adjusted for Marital Status

	Mortality odds ratios (95% CI)			
	All of healthcare industry	**Physicians**	**Nurses (RNs and LPNs)**	**Laboratory technicians**
HIV				
HIV in time period 1 (1984−1991)				
Males	2.34 (2.03−2.69)	1.73 (1.03−2.90)	4.43 (2.84−6.91)	1.43 (0.80−2.56)
Females	1.14 (0.93−1.40)	1.52 (0.13−17.53)	1.06 (0.74−1.52)	1.12 (0.32−3.93)
HIV in time period 2 (1992−1999)				
Males	2.25 (2.06−2.46)	1.39 (0.97−1.98)	3.53 (2.70−4.63)	2.56 (1.72−3.79)
Females	0.99 (0.89−1.09)	0.56 (0.19−1.66)	0.59 (0.48−0.74)*	0.68 (0.38−1.23)
HIV in time period 3 (2003−2004)				
Males	1.38 (0.65−2.95)	a	0.66 (0.11−4.04)*	0.53 (0.029−9.81)
Females	1.00 (0.31−3.20)	a	0.37 (0.04−3.78)	0
HIV in all years combined				
Males	2.27 (2.11−2.44)	1.50 (1.12−2.01)	3.67 (2.92−4.61)	2.12 (1.54−2.93)
Females	1.01 (0.93−1.11)	0.67 (0.25−1.75)	0.69 (0.57−0.83)	0.72 (0.43−1.23)
HBV				
HBV in time period 1 (1984−1991)				
Males	1.58 (1.08−2.32)	1.50 (0.64−3.51)	16.28 (3.59−73.78)	4.87 (0.78−30.56)
Females	1.20 (0.84−1.70)	3.37 (0.21−54.49)	1.02 (0.58−1.82)	12.64 (1.40−113.99)
HBV in time period 2 (1992−1999)				
Males	2.25 (1.69−2.99)	3.05 (1.43−6.52)	5.30 (1.99−14.11)	2.41 (0.76−7.72)
Females	1.11 (0.81−1.52)	b	1.11 (0.70−1.77)	2.70 (0.77−9.50)
HBV in time period 3 (2003−2004)				
Males	2.07 (0.71−6.06)	3.12 (0.19−50.71)	0	a
Females	0.18 (0.02−1.73)	0	0	a
HBV in all years combined				
Males	1.98 (1.58−2.48)	2.24 (1.30−3.87)	5.90 (2.88−12.10)	2.98 (1.12−7.93)
Females	1.11 (0.88−1.40)	5.11 (0.84−30.99)	1.02 (0.71−1.45)	4.30 (1.52−12.14)
HCV				
HCV in time period 1 (1984−1991)				
Males	1.44 (0.87−2.39)	1.81 (0.66−4.97)	2.36 (0.15−38.07)	4.47 (0.75−26.81)
Females	1.32 (0.93−1.89)	0	1.77 (1.07−2.92)	0
HCV in time period 2 (1992−1999)				
Males	1.55 (1.26−1.91)	1.28 (0.70−2.34)	3.10 (1.45−6.62)	2.40 (0.89−6.46)
Females	1.23 (1.04−1.45)	0.95 (0.10−9.21)	1.08 (0.83−1.41)	1.23 (0.51−2.95)
HCV in time period 3 (2003−2004)				
Males	1.07 (0.64−1.80)	1.71 (0.31−9.40)	0.92 (0.29−2.86)	1.48 (0.13−16.63)
Females	0.99 (0.64−1.53)	0	0.90 (0.45−1.81)	5.77 (0.52−64.10)
HCV in all years combined				
Males	1.46 (1.22−1.75)	1.41 (0.86−2.32)	2.09 (1.16−3.79)	2.64 (1.18−5.89)
Females	1.22 (1.05−1.40)	0.49 (0.06−4.05)	1.15 (0.92−1.43)	1.23 (0.57−2.66)
Liver cancer				
Liver cancer in time period 1 (1984−1991)				
Males	1.07 (0.90−1.27)	1.21 (0.83−1.75)	1.09 (0.43−2.79)	0.22 (0.03−1.72)
Females	1.06 (0.94−1.19)	2.37 (0.53−10.62)	1.04 (0.87−1.24)	1.48 (0.67−3.28)
Liver cancer in time period 2 (1992−1999)				
Males	1.19 (1.03−1.39)	1.30 (0.95−1.79)	1.15 (0.48−2.75)	2.19 (0.88−5.45)*
Females	0.88 (0.80−0.98)*	1.39 (0.53−3.65)	0.84 (0.72−0.99)	0.66 (0.31−1.41)

(Continued)

TABLE III. (*Continued*)

	Mortality odds ratios (95% CI)			
	All of health-care industry	**Physicians**	**Nurses (RNs and LPNs)**	**Laboratory technicians**
	Liver cancer in time period 3 (2003−2004)			
Males	0.78 (0.47−1.29)	0.83 (0.27−2.52)	0.61 (0.07−5.27)	0
Females	0.77 (0.54−1.08)	0	0.60 (0.33−1.07)	3.07 (0.43−21.88)
	Liver cancer all years combined			
Males	1.11 (1.00−1.24)	1.24 (0.98−1.57)	1.06 (0.58−1.95)	1.00 (0.47−2.15)
Females	0.94 (0.87−1.01)	1.44 (0.65−3.18)	0.91 (0.81−1.02)	1.00 (0.60−1.68)
Cirrhosis				
	Cirrhosis in time period 1 (1984−1991)			
Males	1.10 (1.02−1.18)	1.12 (0.96−1.32)	0.95 (0.65−1.39)	1.35 (0.87−2.09)
Females	1.02 (0.97−1.07)	1.18 (0.70−1.98)	1.04 (0.96−1.11)	1.26 (0.93−1.71)
	Cirrhosis in time period 2 (1992−1999)			
Males	1.09 (1.01−1.18)	1.02 (0.85−1.22)	1.19 (0.85−1.65)	1.49 (0.95−2.32)
Females	1.02 (0.97−1.07)	1.09 (0.63−1.90)	1.02 (0.95−1.10)	1.16 (0.87−1.56)
	Cirrhosis in time period 3 (2003−2004)			
Males	0.99 (0.75−1.30)	0.57 (0.25−1.29)	1.56 (0.62−3.92)	0.24 (0.03−1.84)
Females	1.00 (0.85−1.18)	0.43 (0.05−3.49)	0.84 (0.63−1.11)	1.83 (0.66−5.02)
	Cirrhosis in all years combined			
Males	1.09 (1.04−1.15)	1.06 (0.94−1.19)	1.10 (0.87−1.40)	1.30 (0.96−1.77)
Females	1.02 (0.99−1.06)	1.09 (0.75−1.58)	1.02 (0.97−1.07)	1.23 (1.00−1.51)

[a]Undefined; no exposed cases or controls.
[b]Unstable; no exposed controls.
*MOR significantly different than MOR for time period 1 ($P < 0.05$).

borne pathogens. Although this may partially explain the positive associations found in our study, the CDC has evidence of occupational transmission for only 57 of the 24,844 US health-care workers who have contracted AIDS [Chamberland et al., 1991; Do et al., 2003; CDC, 2006b]. Fifty-seven is likely a serious underestimate of true occupationally acquired AIDS cases because occupational attribution requires documentation of seroconversion after a specific exposure event and surveillance procedures classify all health-care workers with AIDS who report nonoccupational risk factors for HIV as nonoccupational cases. On the other hand, it is highly unlikely that a majority of AIDS (and HBV and HCV) cases among health-care workers classified as nonoccupational are truly occupational since previous laboratory and epidemiological studies have demonstrated that HIV, HBV, and HCV are not easily transmitted through sharps injuries [CDC, 2001].

One of our most striking findings was an increased risk for death due to HIV and HBV among male nurses. According to the Current Population Survey, the percentage of males among registered nurses ranged from 6.5% to 8.7% (about 133,000−220,000 total male registered nurses) from 1995 through 2006, and the percentage of males among licensed practical and licensed vocational nurses ranged from 4.0% to 6.6% (about 15,000−34,000 total male licensed practical and vocational nurses) [BLS, 2007]. The fact that female nurses

in our study had a decreased risk of dying from HIV compared to other workers, and assuming that most HIV infections are caused by nonoccupational factors, suggests that female nurses may be less likely than other workers to participate in nonoccupational risk behaviors for HIV, perhaps due to their health knowledge. However, it is unclear why other groups of health-care workers, including male nurses, appear to be more likely to participate in nonoccupational risk behaviors for HIV.

Secular Trends

Due to increasing availability of HBV vaccine over time and a decreased risk of dying from HIV, HBV, or HCV once acquired due to early detection and increasingly effective therapeutic interventions [Crook et al., 2003], we expected health-care workers to have higher MORs for dying of bloodborne pathogens and their sequelae (liver cancer and cirrhosis) during the first time period of our study (1984−1991) than in the later time periods (1992−1999 and 2003−2004), but we did not find this to consistently be the case. One reason for this may be the long and variable time lag between acquisition of infection and death. For example, average life expectancy at the age of 20 years for HIV-infected persons treated with antiretroviral therapy has increased from 9.1 years in 1993−1995 to 23.6 years in 2002−2004, with

large standard deviations [Lima et al., 2007]. Also, the rates of development of cirrhosis and liver carcinoma among persons with chronic HBV or HCV infection gradually increase for at least 15 years after diagnosis of the infection [Ikeda et al., 1998], with deaths occurring even later. Thus, many deaths in the 2003–2004 time period may represent deaths of health-care workers who acquired infections before the OSHA Bloodborne Pathogen Standard took effect in 1991 and was revised in 2001. A trend related to these regulations might not be evident for many more years.

AIDS Among Health-Care Workers

We found the strongest association between employment in the health-care industry and death due to bloodborne pathogens among males dying of HIV/AIDS. Through 2001, approximately 5% of individuals in the U.S. with AIDS reported to the CDC had been employed in health care settings, but less than 0.2% (26 persons since 1985) of health-care workers with AIDS were documented to have become HIV positive following occupational exposure [Do et al., 2003].

Ninety-one percent of the health-care workers with AIDS documented by the CDC's HIV/AIDS Reporting System through 2001 reported non-occupational risks for HIV infection (e.g., sexual risk behaviors, injection drug use, or transfusion) [Do et al., 2003]. As of 1988, health-care workers with AIDS were significantly less likely than others with AIDS to report intravenous drug use and more likely to be men who had sex with men [CDC, 1988].

In our analysis of NOMS data, mortality odds ratios varied by occupation. Nursing was the occupation with the highest MOR among males for HIV, but female nurses were at decreased risk of dying from HIV. A few studies have reported sexual risk behaviors among physicians, but we know of no such studies among nurses or other health-care workers [Klein et al., 1987; Wolcott et al., 1990; Williams and Goebert, 2003].

In order to assess the prevalence of nonoccupational risk factors for HIV among health-care workers, we analyzed publicly available data from the National Health Interview Survey (NHIS; available at http://www.cdc.gov/nchs/about/major/nhis/quest_data_related_doc.htm) using SAS survey procedures (PROC SURVEYFREQ) to account for the complex sample design. The NHIS has collected data on the prevalence of HIV risk factors in the U.S. population since 1988, which can be analyzed by industry and occupation [National Center for Health Statistics—NCHS, 2007]. Participants are asked whether any of a group of risk statements applies to them, but are not asked which statement applies. The specific risk statements have changed slightly over the years, but include: having hemophilia and having received clotting factor concentrates, being a man who has

had sex with another man, having taken illegal drugs by needle, having immigrated to the US from an AIDS-endemic region, having exchanged sex for money or drugs, being the sex partner of someone with one or more of the previous risk factors, and having a positive HIV test. Combining data from 1988 through 2003, the prevalence of one or more of these risk factors is 3.1% among all males and 2.0% among all females. Among all persons employed in the health-care industry, the prevalence is 4.7% among all males and 2.1% among all females; among persons employed in health assessment and treating occupations (which includes nurses), the prevalence is 5.3% among males and 1.5% among females. Therefore evidence exists to suggest that the prevalence of nonoccupational risk factors for HIV is higher among those employed in the health-care industry, varies by occupation within the health-care industry, and that the male to female discrepency is more pronounced among health-care workers than among the general population.

HBV Among Health-Care Workers

We found an association between employment in the health-care industry and death due to HBV among males in every patient care occupational group, but only among female laboratory technicians. In fact, the strongest MORs found in our study were for HBV among male nurses (16.28) and among female laboratory technicians (12.64) from 1984 to 1991. There is more evidence in the literature supporting occupational acquisition of HBV infection than there is for HIV. This evidence includes seroprevalence studies, performed in the 1970s through early 1990s, that show a much higher prevalence of markers for HBV infection among health-care workers than among the general public and at least one prospective surveillance study showing an increased incidence of new infections among health-care workers compared to controls. Nurses and other personnel with frequent blood contact had the greatest risk of serologic evidence of HBV [Pattison et al., 1975; Janzen et al., 1978; McLean et al., 1987; Gibas et al., 1992; Thomas et al., 1993; Panlilio et al., 1995].

HBV vaccine became widely available in the 1990s. Fortunately, successfully immunized health-care workers are at decreased risk for HBV infection, and post-exposure prophylaxis with HBV immune globulin and vaccine is more than 90% effective [NIOSH, 2001]. Unfortunately, not all eligible health-care workers receive the vaccine. A cluster sample of employees of 113 hospitals in 1994–1995 found that 90% of employees were eligible to receive HBV vaccine, but only 66.5% of them had received the recommended three doses [Mahoney et al., 1997]. According to data from the National Health Interview Survey, only 80.5% of US health-care workers between the ages of 18 and 49 had received at least one dose of HBV vaccine by 2004 [CDC, 2006a].

HCV Among Health-Care Workers

We found an association between employment in the health-care industry and death from HCV among both males and females when data from all time periods were combined, with the highest occupational MORs occurring among male laboratory technicians and male nurses. HCV is less readily transmissible through sharps injuries than HBV, with an estimated seroconversion rate of 0–7% (average = 1.8%) after percutaneous exposure [CDC, 2001]. It has been estimated that this leads to 50–150 transmissions of HCV among health-care workers annually, assuming that hospitalized patients have the same HCV seroprevalence as the rest of the U.S. population [Sepkowitz and Eisenberg, 2005]. In 2005, employment in a medical or dental field was recorded for 7.2% of acute cases of HCV reported to CDC with available risk factor data (an increase from previous years). In comparison, injection drug use was reported for 50% of cases and multiple sex partners were reported for 23% [CDC, 2007]. Seroprevalence studies of HCV in health-care workers suggest minimally increased risk compared with the general population [Thomas et al., 1993; CDC, 2001]. Immunization against HCV is not available, and there is no recommended regimen for post-exposure prophylaxis [CDC, 2001].

Given the consistency of our findings for males and females regarding HCV, in contrast to HIV/AIDS, our results suggest that health-care workers are at increased risk of death due to HCV due to exposures to infectious body fluids, which might have occurred prior to enactment of OSHA bloodborne pathogen standards. Some HCV infections among health-care workers may have been acquired through blood transfusions prior to universal testing of the blood supply for HCV, but we know of no evidence to indicate that health-care workers are more likely to receive blood transfusions than other workers. We also know of no evidence that workers in the health-care industry have an increased rate of injection-drug use, currently the most common nonoccupational risk factor for HCV. Reported rates of illicit drug use among health diagnosing and treatment practitioners (including physicians and RNs) and technicians and related support (including LPNs and laboratory technicians) occupational categories are lower than among all workers [Substance Abuse and Mental Health Services Administration—SAMHSA, 2006, 2007]. Finally, as previously discussed with regards to HIV, there is little information available in the literature about the prevalence of sexual risk behaviors among health-care workers compared to other workers.

Deaths From Chronic Liver Disease (Carcinoma or Cirrhosis) Among Health-Care Workers

Given our interest in the risk of dying from HBV and HCV, we were also interested in deaths from their liver sequelae. These infections are associated with an increased risk of dying from carcinoma of the liver and cirrhosis [Crook et al., 2003; Amin et al., 2006]. We found statistically significant MORs for these two diseases among male health-care workers during some of the time periods studied, but these MORs were not as high as those associated with deaths directly linked to bloodborne pathogens. This may be related to the fact that only a portion of persons who die of these causes have bloodborne pathogen infections or to the fact that we excluded cases with evidence of alcohol-related causes of death from the analysis. Alcohol is an important cofactor in deaths from chronic liver disease among persons with chronic viral hepatitis. Hepatocellular carcinoma (HCC) is the most common form of primary liver cancer. Although chronic HBV is the predominant risk factor for HCC worldwide, HCV is a more important factor in the United States. In the US, 50% of HCC cases are solely related to HCV and 20% are related to a combination of HCV and alcohol [Hayashi and Di Bisceglie, 2005]. Approximately 10% of cirrhosis cases are caused by chronic HBV or C, compared to 60–70% of cases caused by alcohol [Heidelbaugh and Bruderly, 2006].

LIMITATIONS

There are several limitations to this study related to the use of death certificates. First, the industry and occupation may be the final, usual, or most prestigious job, and may reflect erroneous recollections of occupation by the next of kin. Complete occupational histories were unavailable. Furthermore, almost 30% of the available NOMS records had either no occupation or industry information or a nonspecific entry (e.g., homemaker, retiree). The proportion of records excluded from analyses due to occupation or industry codes differed by sex; 52.65% of females met this exclusion criterion, compared to 7.14% of males. Specifically, 50.22% of all female records had industry coded as "own home/at home," compared to 2.28% of all male records.

There is some evidence that the control groups in our study are representative of all US workers. As shown in Table II, when all time periods are combined, the proportion of females employed in the health-care industry in our control groups varied from 13.9% to 17.8%, while the proportion of females employed in nursing occupations in our control groups varied from 4.5% to 6.1%. As a comparison, the 2000 Current Population Survey (http://www.bls.gov/cps/cpsa2000.pdf), indicates that 14.4% of all female US workers were employed in the health-care industry (compared to 3.5% of all male workers) and 3.7% of all female US workers were employed in nursing occupations (RNs and LPNs) at a timepoint between the last two periods of our study.

Second, the diagnoses provided on the death certificate may be erroneous or incomplete, leading to disease misclassification. This may have occurred to a greater extent during the earliest time period studied, when deaths related to

HIV or viral hepatitis may not have been recognized as such. We attempted to minimize disease misclassification by using the underlying and contributing causes of death when identifying cases. There is also the potential for differential detection of HIV or other infections in health-care workers compared to persons employed in other industries. Third, the limited number of deaths available in NOMS for 2003 and 2004 due to the relatively few states participating in these years, as well as the lack of any data for 2000–2002 limited the power to both detect associations during this most recent time period and to establish trends over time.

The greatest limitation to our study was that information was not available on possible confounding factors such as sexual risk behaviors, history of blood transfusions, intravenous drug use, and alcohol use. We attempted to partially control for sexual risk behaviors by stratifying on marital status, because we found that being married at the time of death was negatively associated with deaths from HIV and hepatitis, but marital status is not necessarily a good proxy for sexual risk behaviors. We also attempted to control for alcohol use in the analyses of liver cancer and cirrhosis by excluding records with alcohol-related causes of death from being cases or controls, but a history of excessive alcohol intake might not have been recognized and recorded.

Finally, our study was limited by an inability to calculate mortality rates due to a lack of denominator data.

CONCLUSIONS

Employment in the health-care industry was found to be associated with deaths from three examined bloodborne pathogens and their sequelae among males, but only with HCV among females in this exploratory study. The previous literature on incidence of bloodborne pathogen infections, especially HIV, suggests that most cases occurring among health-care workers are not due to occupational exposures (i.e., sharps injuries). One explanation for our findings is that employment in the health-care industry is a surrogate for non-occupational risk factors for these infections, especially among males. Research is needed to understand why, despite their probably high degree of knowledge about the transmission of HIV and hepatitis, male health-care workers still engage in these risk behaviors. Targeted interventions to decrease the risk of bloodborne pathogens among health-care workers may need to be gender-specific.

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