Percutaneous Injury, Blood Exposure, and Adherence to Standard Precautions: Are Hospital-Based Health Care Providers Still at Risk?

Bradley N. Doebbeling,[1,2,3,a] Thomas E. Vaughn,[4] Kimberly D. McCoy,[2] Susan E. Beekmann,[2] Robert F. Woolson,[6] Kristi J. Ferguson,[5] and James C. Torner[3]

[1]Program in Health Services Research, Veterans' Affairs Medical Center, [2]Department of Internal Medicine, University of Iowa Carver College of Medicine, and Departments of [3]Epidemiology, [4]Health Management and Policy, and [5]Community and Behavioral Health, University of Iowa College of Public Health, Iowa City, Iowa; and [6]Department of Biometry and Epidemiology, Medical College of the University of South Carolina, Charleston

To examine factors associated with blood exposure and percutaneous injury among health care workers, we assessed occupational risk factors, compliance with standard precautions, frequency of exposure, and reporting in a stratified random sample of 5123 physicians, nurses, and medical technologists working in Iowa community hospitals. Of these, 3223 (63%) participated. Mean rates of hand washing (32%–54%), avoiding needle recapping (29%–70%), and underreporting sharps injuries (22%–62%; overall, 32%) varied by occupation ($P < .01$). Logistic regression was used to estimate the adjusted odds of percutaneous injury (aOR_{injury}), which increased 2%–3% for each sharp handled in a typical week. The overall aOR_{injury} for never recapping needles was 0.74 (95% CI, 0.60–0.91). Any recent blood contact, a measure of consistent use of barrier precautions, had an overall aOR_{injury} of 1.57 (95% CI, 1.32–1.86); among physicians, the aOR_{injury} was 2.18 (95% CI, 1.34–3.54). Adherence to standard precautions was found to be suboptimal. Underreporting was found to be common. Percutaneous injury and mucocutaneous blood exposure are related to frequency of sharps handling and inversely related to routine standard-precaution compliance. New strategies for preventing exposures, training, and monitoring adherence are needed.

In 1987, the Centers for Disease Control and Prevention (CDC) proposed universal precaution guidelines recommending routine barrier precautions for anticipated contact with blood or certain bodily fluids [1]. In 1989, these guidelines were updated to include more specific recommendations, including precautions to be used during phlebotomy [2]. The Occupational Safety and Health Administration (OSHA) published its Blood-Borne Pathogens Rule in 1991 [3], which requires training of all workers at risk, implementation of universal precautions, and monitoring of compliance. These guidelines, which were designed to protect workers from sharps injuries, continue to be revised. In 1996, the CDC combined universal precautions with body-substance isolation recommendations in "standard" precautions [4]. Similarly, OSHA updated its guidelines for the use of safety devices and enforcement [5].

We recently reported on hospital bloodborne-pathogen training and exposure surveillance programs in 153 hospitals [6]. New-employee training was offered no more than twice per year by one-third of the institutions we studied. Most facilities monitored compliance of nurses, housekeepers, and laboratory technicians; physicians were rarely trained or monitored. Protected devices for phlebotomy or intravenous placement were purchased by one-third of the institutions. Percutaneous injury surveillance relied on incident re-

Received 22 January 2003; accepted 21 May 2003; electronically published 24 September 2003.

Financial support: Centers for Disease Control and Prevention/National Institute for Occupational Safety and Health (cooperative agreement no. U60/CCU172173).

[a] Present affiliation: Department of Internal Medicine, Indiana University School of Medicine, Indianapolis.

Reprints or correspondence: Dr. Bradley N. Doebbeling, Health Services Research (11H), Roudebush Veterans Affairs Medical Center, 1481 W. 10th St., Indianapolis, IN 46202 (bdoebbeling@hsrd.va.iupui.edu).

Clinical Infectious Diseases 2003; 37:1006–13

1058-4838/2003/3708-0002$15.00

ports and employee health records. The annual reported percutaneous injury incidence, from institutional incident reports, was 5.3 injuries/100 personnel. Thus, passively reported injury rates remained high.

Most studies have involved a single institution, typically a large academic medical center [7–18]. Few have examined >1 hospital [17, 19] or assessed compliance across institutions and communities [17, 20]. Most have relied on passive incident reporting; thus, reported rates are likely biased toward underestimation. Only 2 studies of nurses have used active case ascertainment [17, 19]. The purpose of the present study is to estimate the level of standard-precaution adherence, occupational injury and exposure rates, and rates of underreporting among health care workers practicing in community hospitals who are at risk for blood exposure.

METHODS

Percutaneous injury and mucocutaneous blood exposure rates were directly assessed in stratified random samples of different occupational groups of health care workers in Iowa during 1997. A mail survey was conducted to identify the most important occupational risk factors, to assess attitudes toward the use of precautions, and to estimate occupational exposures. Appropriate informed consent was obtained, and the guidelines for human experimentation of the University of Iowa Internal Review Board and the United States Department of Health and Human Services were followed.

Sample. The primary goal was to accurately estimate current percutaneous blood exposure rates within different occupations. The sampling frame included statewide professional organization databases. Respondents were stratified on the basis of the size (number of beds) of the largest hospital in the county of workplace. Stratified random subsamples of physicians, nurses, laboratory technicians, and medical technologists were identified within the size strata.

The sample was limited to health care workers who provided direct patient care; the selection was aimed at identifying those who were specifically at risk of blood exposure. Excluded workers included (1) physicians whose primary activity was administration or teaching, (2) nurses and medical technologists who were not employed in hospitals, (3) nuclear medicine technologists, and (4) workers at the state's tertiary care referral center. The final sample included 5364 health care workers: 20% of the registered nurses, licensed practical nurses, and physicians and 40% (oversampled) of the medical technologists in Iowa.

Study instrument. To maximize participation, the survey instrument length was limited; predefined categorical responses, with neutral phrasing, were primarily used. The survey was pilot-tested in clinic and community hospital settings, respondents were interviewed, and the survey was revised.

Data elements. The outcomes of interest were occupational sharps injuries and mucocutaneous blood exposures, proportion of injuries reported, and adherence to standard-precaution guidelines. Respondents were asked to estimate the number of (1) exposures of skin, mouth, eyes, and/or nose to blood; (2) total sharps injuries; (3) hollow-bore–needle injuries; and (4) solid-needle injuries in the past 3 months. This 3-month time period was used to minimize recall bias but still obtain adequate precision of the estimates [21–23]. Respondents were also asked how many of these exposures they had reported or formally documented. The results of this method of assessing sharps injuries agree well with clinic records [24].

Rates of underreporting were estimated as the proportion of the reported exposures among the actual exposures for each worker. An overall mean was also calculated for each occupation to examine differences by occupation. Reported standard-precaution compliance was grouped into low (0%–79%), moderate (80%–99%), and high (100%) compliance levels. The potential for exposure and for sharps injuries is affected by the number of sharps handled. Therefore, a control variable was created, representing the midpoints of the frequency categories for different sharps devices used in a typical week.

Compliance with key standard-precaution measures [25] was estimated along a 10-cm visual analogue scale and extrapolated to a 0%–100% scale. Respondents estimated what percentage of the time they typically (1) wore gloves when performing an invasive procedure (e.g., drawing blood), (2) washed their hands after patient contact before caring for the next patient, and (3) recapped needles after use before disposing of them in a sharps container. The phrasing of these questions denoted specific patient care settings in which compliance should be routine. Occupational risk factor data included occupation, clinical work sites, experience, typical hours at risk per week, no. of different sharps devices handled in a typical week, and hospital practice.

Survey methods. A modified Dillman method was used for mailings, with various strategies to maximize response rates [26–31]. A cover letter, information summary, survey, and self-addressed, stamped envelope were mailed in January 1997. The cover letter acknowledged collaboration and funding by the CDC and the National Institute for Occupational Safety and Health. A support letter from state public health authorities was included. A postcard reminder and a "collect call" telephone number for questions or a new survey were mailed several weeks later. The entire packet was then remailed to nonresponders at 4- and 6-week intervals.

Refining the population at risk. To more precisely estimate injury and exposure rates, we further refined the population at risk (denominator). Respondents were considered not to be at risk ($n = 23$) if they met all 3 exclusion criteria (primary work site in an office, no time providing patient care or handling specimens in a typical week, and no sharps handling in a typical week) and reported no percutaneous injuries or blood exposures. These respondents were excluded from analyses other than that of the characteristics of responders and nonresponders (table 1).

Statistical analysis. Descriptive statistics, variable scaling, and bivariate relationships were assessed. Contingency table analyses of the association between demographic and occupational variables and either percutaneous injury or mucocutaneous blood exposure were assessed with a χ^2 test for nominal and ordinal variables. Continuous variables were examined with Student's *t* test or the Wilcoxon rank sum test, as appropriate. The sociodemographic characteristics of responders were compared with those of nonresponders. Nonresponse bias was also assessed by comparing the rates of injury and blood exposure by time of response to each mailing. Two-tailed 95% CIs were used for all analyses. All analyses were performed using SAS software (SAS Institute).

The protective effect of recommended preventive measures against any percutaneous injury in the previous 3 months was estimated using logistic regression analysis. ORs from logistic regression estimated this effect, after adjusting for time spent providing patient care or handling specimens and for the number of sharps handled in a typical week. The relationship between any mucocutaneous blood exposure during the previous 3 months and the adjusted odds of sharps injury during the same period was assessed similarly. Each logistic regression model was applied to the entire sample and used in separate analyses in which respondents were stratified by occupation.

RESULTS

Surveys were mailed to 5364 persons; 3223 surveys were completed. Of the returned surveys, 241 were considered to be ineligible for inclusion (because of lack of patient contact, retirement, or incorrect address), for an adjusted overall response of 63%. Responders and nonresponders did not differ statistically on the basis of sociodemographic characteristics (age, sex, and race). Physician responders and nonresponders did not differ on the basis of specialty.

The distribution of types of employment among participants was representative of that among health care workers in the state: 67% of respondents were registered nurses, and 15% were physicians (table 1). The sex distribution was predominantly female, except among physicians, which is consistent with the population. The race and ethnicity of the sample reflected the distribution among Iowans in general. The majority of participants reported hospital practice.

Table 1. Descriptive characteristics of 3223 health care workers included in a survey of percutaneous exposure risks in different occupational groups.

Variable, respondent group	Value
Occupation	
Physician	485 (15.0)
Registered nurse	2168 (67.3)
Licensed practical nurse	249 (7.7)
Medical technologist	321 (10.0)
Female sex	2602 (84.0)
Physicians	66 (15.6)
Registered nurses	2040 (96.4)
Licensed practical nurses	230 (94.6)
Medical technologists	266 (85.0)
Race/ethnicity	
White, non-Hispanic	2954 (96.5)
Other	108 (3.5)
Hospital practice	2822 (89.5)
Primary work site	
General inpatient unit	790 (25.6)
Office or clinic	559 (18.1)
Operating room	299 (9.7)
Clinical laboratory or blood bank	284 (9.2)
Intensive care unit	216 (7.0)
Emergency department	188 (6.1)
Labor and delivery	168 (5.4)
Other	579 (18.8)
Years of health care employment, median (IQR)	17 (8–24)
Physicians	16 (10–25)
Registered nurses	16 (8–24)
Licensed practical nurses	18 (4–25)
Medical technologists	17 (10–23)
Hours per week at risk,[a] median (IQR)	32 (20–40)
Physicians	50 (40–60)
Registered nurses	30 (20–40)
Licensed practical nurses	30 (20–40)
Medical technologists	32 (20–40)

NOTE. Data are no. (%) of respondents, unless otherwise indicated. Denominators used to calculate percentages vary, because complete data were not available for all subjects. IQR, interquartile range.

[a] No. of hours dedicated to patient care and handling of specimens.

Primary work sites included general inpatient units, physician offices or clinics, operating rooms, and clinical laboratories or blood banks. Many worked in >1 clinical setting. The median duration of health care experience was 17 years since training. The median period at risk for exposure per week (due to direct patient care or handling specimens) was 32 h; physicians reported a median of 50 h/week.

Sharps handling. The proportion of workers who rou-

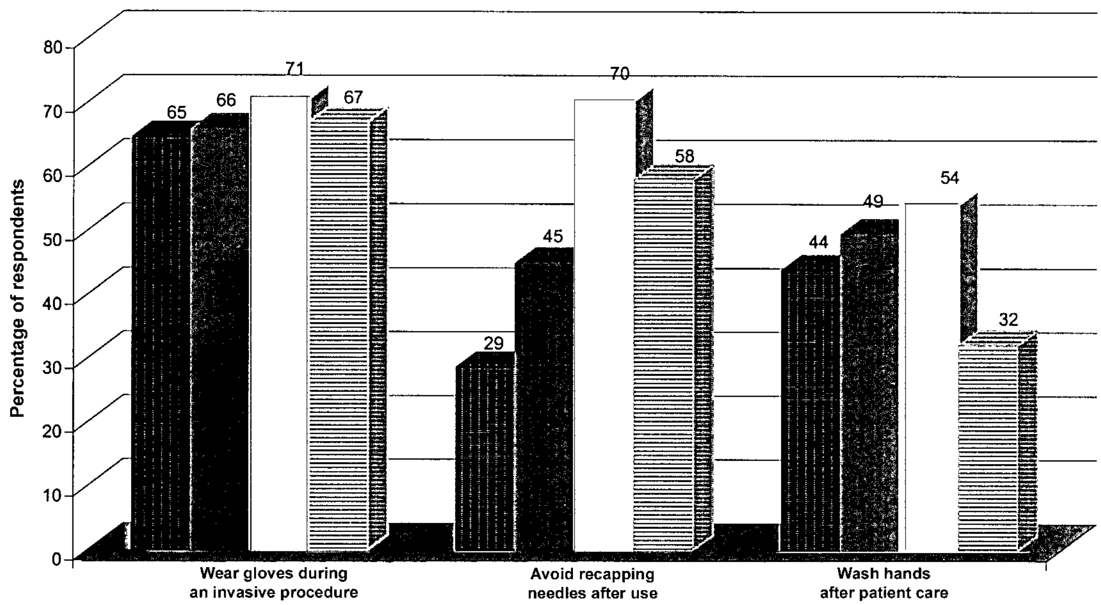

Figure 1. Use of standard precautions among 3200 health care workers in Iowa, by occupation. *Black columns,* physicians; *gray columns,* registered nurses; *white columns,* licensed practical nurses; and *striped columns,* medical technologists.

tinely handled sharps varied significantly across occupations for each of the sharps device types ($P < .01$, by χ^2 test; data not shown). Hollow-bore needles were routinely handled most often by medical technologists (41% reported handling >20 hollow-bore needles/week) and registered nurses (20% reported handling >20 hollow-bore needles/week). Physicians routinely handled more solid devices (15% handled >20 solid devices/week) and other sharps, such as lancets and scalpels (24% handled >10 such devices/week). Licensed practical nurses routinely handled the fewest sharps devices.

Use of standard precautions. Two-thirds of workers reported routinely wearing gloves when performing an invasive procedure (figure 1). Rates of always avoiding needle recapping varied significantly by occupation; compliance was lowest among physicians (29% reported never recapping needles) and the highest among licensed practical nurses (70%). Reported hand washing after patient contact also varied significantly, with the highest rates of routine hand washing reported among licensed practical nurses (54%) and the lowest among medical technologists (32%).

Blood exposure. Occupational blood exposures also varied by occupation (table 2). Two-fifths (43%) of physicians had experienced ⩾1 mucocutaneous blood exposure in the previous 3 months; 8% had experienced ⩾5. More than one-third (39%)

Table 2. Frequency of blood exposure and sharps injuries among health care workers in the 3 months before survey administration, by occupation.

Exposure type, respondent group	No. (%) of respondents with indicated no. of exposures				
	0	1	2	3–4	⩾5
Mucocutaneous blood exposure					
Physicians	260 (57.0)	68 (14.9)	55 (12.1)	38 (8.3)	35 (7.7)
Registered nurses	1305 (61.5)	357 (16.8)	234 (11.0)	143 (6.7)	84 (4.0)
Licensed practical nurses	182 (73.7)	32 (13.0)	15 (6.1)	16 (6.5)	2 (0.8)
Medical technologists	240 (75.5)	40 (12.6)	15 (4.7)	13 (4.1)	10 (3.1)
Sharps injury					
Physicians	324 (71.7)	58 (12.8)	21 (4.6)	22 (4.9)	27 (6.0)
Registered nurses	1439 (68.1)	343 (16.2)	189 (8.9)	104 (4.9)	39 (1.8)
Licensed practical nurses	185 (75.8)	34 (13.9)	20 (8.2)	5 (2.0)	0 (0.0)
Medical technologists	230 (72.6)	45 (14.2)	21 (6.6)	13 (4.1)	8 (2.5)

Table 3. Proportions of health care workers injured and estimated percutaneous injury rates in the 3 months before survey administration, by occupation.

Variable	All workers (n = 3127)	Physicians (n = 452)	Registered nurses (n = 2114)	Licensed practical nurses (n = 244)	Medical technologists (n = 317)
No. (%) of respondents injured	949 (30.3)	128 (28.3)	675 (31.9)	59 (24.2)	87 (27.4)
Mean rate of sharps injuries[a]					
All	0.62	0.75	0.62	0.37	0.57
Hollow bore	0.46	0.29	0.50	0.25	0.49
Solid needle	0.27	0.59	0.20	0.23	0.04

NOTE. Injury rates were estimated using a ridit approach with the midpoint of the range entered. Thus, for respondents reporting 3–4 injuries, the midpoint of 3.5 was used; for respondents reporting >5 injuries, the value of 6 was substituted.

[a] No. of injuries per worker in a 3-month period.

of registered nurses had experienced ⩾1 mucocutaneous blood exposure in the previous 3 months. One-fourth (27%) of licensed practical nurses and one-fourth (25%) of medical technologists had experienced a mucocutaneous blood exposure in the same interval.

Percutaneous injury. Nearly one-third (30%) of respondents had experienced ⩾1 percutaneous injury in the previous 3 months (table 3). Registered nurses were injured most often (32% reported ⩾1 injury), followed by physicians (28%) and medical technologists (27%); licensed practical nurses were injured least often (24%). The overall sharps injury rate was 0.62 injuries per worker per 3 months. Physicians experienced the highest rate of injuries, 0.75 injuries per worker per 3 months, followed by registered nurses (0.62) and medical technologists (0.57). Licensed practical nurses had the lowest rate (0.37). Registered nurses and medical technologists experienced the highest hollow-bore–needle sharps injury rate, whereas physicians had the highest rate of solid-needle injuries.

Exposure reporting. Overall, one-third of the percutaneous injuries were unreported or were not formally documented (table 4). Underreporting of sharps injuries varied by number of injuries, occupation, and type of exposure. Most workers (405 [84%] of 480) who had experienced a single percutaneous injury in the previous 3 months had reported or formally documented it. In contrast, two-thirds (91 [63%] of 144) of those with 3 or 4 sharps injuries in the same period reported all injuries. One-fourth (18 [24%] of 74) of those who experienced ⩾5 sharps injuries noted that they had reported ⩾4 injuries. Underreporting also varied by occupation; the highest rate of underreporting (62%) was among physicians. Relatively few mucocutaneous blood exposures were reported (by 12% of respondents overall).

Risk of sharps injury. Increased frequency of handling sharps devices per week, regardless of type, was strongly associated with increased odds of sustaining a percutaneous injury for the overall sample (table 5). These models controlled for time at risk. Similar increases were seen in analyses stratified by occupation, although the increases did not reach statistical significance in the smaller strata of licensed practical nurses and medical technologists, because the analysis lacked power for some comparisons.

The overall adjusted OR of injury (aOR_{injury}) for those who reported never recapping needles was 0.74 (95% CI, 0.60–0.91). The association between any recent blood contact and adjusted likelihood of injury was 1.57 (95% CI, 1.32–1.86) overall. Physicians had the greatest adjusted risk of percutaneous injury if they had experienced mucocutaneous blood contact in the previous 3 months (aOR_{injury}, 2.18; 95% CI, 1.34–3.54).

DISCUSSION

These data demonstrate that percutaneous injury and mucocutaneous blood contact occur frequently among health care workers in various practice sites. Exposure and injury rates differ by occupation, depending on factors such as the frequency of handling of specific devices, the amount of time spent providing patient care or handling specimens, and the

Table 4. Underreporting of percutaneous injuries in the 3 months before survey administration, by occupation.

Respondent group	Proportion of injuries unreported (no. of respondents)
Physicians	0.62 (125)
Registered nurses	0.27 (667)
Licensed practical nurses	0.34 (54)
Medical technologists	0.21 (85)
All healthcare workers	0.31 (931)

NOTE. "Unreported" refers to exposures that were not reported or formally documented. Rates of underreporting (or failure to formally document) were estimated using the following formula: 1 − (no. of reported exposures/no. of actual exposures for each worker). Overall mean values for each occupation were calculated.

Table 5. ORs indicating the effects of various factors on the odds of a percutaneous injury in the 3 months before survey administration among 3223 health care workers, adjusted for hours at risk and sharps handling.

	OR (95% CI)				
Independent variable	All workers (n = 3200)	Physicians (n = 485)	Registered nurses (n = 2146)	Licensed practical nurses (n = 248)	Medical technologists (n = 321)
Frequency of handling hollow-bore needles[a]	1.02 (1.01–1.03)	1.04 (1.01–1.06)	1.02 (1.01–1.03)	1.03 (0.98–1.07)	1.00 (0.97–1.02)
Frequency of handling solid needles[a]	1.03 (1.02–1.04)	1.07 (1.04–1.09)	1.02 (1.01–1.03)	1.05 (0.99–1.12)	0.96 (0.87–1.05)
Frequency of handling other sharps[a]	1.03 (1.01–1.04)	1.05 (1.02–1.08)	1.02 (1.01–1.03)	1.03 (0.98–1.07)	1.03 (0.99–1.06)
Wearing gloves [b]					
Moderate[c]	0.96 (0.69–1.33)	0.74 (0.33–1.67)	0.80 (0.54–1.20)	NA	0.90 (0.24–3.41)
High[d]	0.84 (0.62–1.13)	0.96 (0.49–1.89)	0.69 (0.48–1.00)	NA	0.86 (0.25–2.92)
Hand washing [b]					
Moderate[c]	0.95 (0.73–1.23)	0.86 (0.46–1.59)	0.99 (0.70–1.41)	0.46 (0.17–1.30)	0.79 (0.39–1.63)
High[d]	0.92 (0.71–1.18)	0.86 (0.47–1.57)	1.01 (0.72–143)	0.37 (0.13–1.00)	0.34 (0.14–0.78)
Not recapping needles[b]					
Moderate[c]	0.99 (0.79–1.23)	1.51 (0.87–2.61)	0.89 (0.68–1.15)	0.54 (0.15–1.95)	0.64 (0.26–1.58)
High[d]	0.74 (0.60–0.91)	0.92 (0.52–1.63)	0.70 (0.54–0.90)	0.60 (0.22–1.63)	0.58 (0.29–1.16)
Blood contact in previous 3 months[e]	1.57 (1.32–1.86)	2.18 (1.34–3.54)	1.46 (1.19–1.79)	1.33 (0.64–2.75)	1.44 (0.75–2.75)

NOTE. ORs were derived from logistic regression models that controlled for time at risk (i.e., no. of hours providing patient care or handling specimens in a typical week and total no. of sharps devices of any type handled per week). "Glove wearing" refers to gloves worn for invasive procedures. "Hand washing" refers to hand washing after patient contact. NA, not applicable (data too sparse to reliably calculate estimates).

[a] Midpoint of range of needles handled per week was used (0, 3, 8, 15.5, and 25, respectively).
[b] Reference category is "low compliance" (0%–79%).
[c] "Moderate" refers to 80%–99% compliance.
[d] "High" refers to 100% compliance.
[e] Reference category is "no exposure."

use of specific standard precautions, particularly never recapping needles. The risk of specific types of injury varies with the frequency of handling of specific sharps. Self-reported compliance with key standard precaution components is disturbingly low. When percutaneous injuries do occur, reporting is infrequent, especially among those who experience multiple injuries.

Our study highlights several important issues. First, occupational blood exposure occurred regularly among medical health care workers in community hospital settings. One-fourth to one-third of the respondents had sustained a percutaneous injury in the previous 3 months, which is comparable to rates from earlier studies [17, 32]. This suggests that percutaneous injury rates have not declined measurably over time. Our data also suggest that occupational injury is common in both urban and rural community hospitals.

Second, risk of injury is directly related to the precautions used. The practice of never recapping needles was associated with an overall reduction in the likelihood of a recent percutaneous injury by one-fourth overall, compared with recapping at least occasionally. Registered nurses who never recapped needles experienced a risk reduction of one-third.

Third, self-reported mucocutaneous blood exposure was associated with an adjusted increased likelihood of injury, which suggests that it is a reliable surrogate for not routinely using isolation materials. Thus, consistent isolation material use also appears to be an important preventive measure. Several studies have shown inadequate adherence to preventive measures, such as recapping needles, routinely wearing gloves for phlebotomy, and hand washing after glove removal [32, 33]. One-fourth of workers in our study had experienced mucocutaneous blood exposure in the previous 3 months. Retraining individuals with such exposures in standard precautions and safe performance of invasive procedures would likely reduce the number of percutaneous injuries and blood exposures.

Fourth, compliance with precautions varied by type of precaution; precautions were taken 29%–70% of the time. Although self-reports of compliance are widely used, they may be overestimates, in comparison with actual or observed compliance [34, 35]. Categorization of these rates in our study into broad strata of low, medium, and high levels of compliance should have minimized misclassification.

Fifth, blood exposure reporting also varies by occupation; physicians infrequently report exposures [15, 36, 37]. Although there is evidence that reporting of blood exposures has increased over time in some settings, reporting remains inadequate [37, 38]. The workers who are most frequently exposed are least likely to document injuries. We observed a clear inverse dose-response relationship between frequency of recent injury and reporting likelihood. Further study of the determinants of underreporting and identification of effective approaches to decrease it are needed to provide effective, timely prophylaxis and educational interventions.

Several potential limitations and some unique strengths of this study should be noted. The study was limited to health care workers in Iowa, which is a largely rural state with relatively few large hospitals. Thus, the results may not be generalizable to other states. However, data from hospitals in Iowa and Virginia suggest that sharps injury rates are comparable in large and small hospitals and in urban and rural areas [39]. In addition, participation or response bias is possible. However, concern over this potential bias is lessened by the response rate, the similarity of participating and nonparticipating subjects, and the comparable risk of injury and exposure reported by early and late responders. Even if all nonresponders had been uninjured, the frequency of sharps injury would be unacceptable.

Furthermore, because the compliance and exposure data were obtained concurrently, it is difficult to ascertain cause and effect. Recent percutaneous injuries could have increased standard-precaution adherence; thus, we may have underestimated the protective effect of avoiding recapping needles, for example. Nevertheless, the strong associations between work-site factors and injury in the expected directions suggest that both occupational factors and failure to adhere to precautions predispose to injury.

One strength of the study is that it evaluated a large, population-based sample of health care workers from urban and rural areas. The similarity between our data on rates of compliance, injury, and exposure and data from large metropolitan hospitals suggests that these results are generalizable. Second, the size of the study allowed identification of important differences in use of precautions, exposure rates, and underreporting by occupation. Another major strength is that similar results are seen in the associations in logistic regression models, which control for modifiable risk factors for injury, as well as in the analyses stratified by occupation. Finally, the methods used enabled demonstration of the protective effect of routine compliance with recommended guidelines, even after adjusting for occupational exposure risk.

Despite the publication of national guidelines, the message about the need for standard precautions and sharps handling safety has not reached many health care workers. Because standard precautions are an effective mechanism for reducing injuries, it is important to tailor educational interventions and sharps protective devices to specific occupations, particular settings, and the types of devices used [40]. Physicians are particularly likely to sustain solid-needle injuries, to be injured repeatedly, and to fail to report injury or exposure. Thus, interventions designed to increase the safety of handling such devices and to facilitate reporting are especially relevant, as are interventions that specifically target physicians.

The epidemiology of percutaneous injury and blood exposure and factors associated with compliance and underreporting need to be better understood. Our results argue for longitudinal surveillance research aimed at identifying trends over time and the impact of interventions. New strategies for education and randomized trials to test alternative strategies should be pursued. In addition, organizational characteristics contributing to compliance need more study [17, 41–44]. Furthermore, protective devices for handling sharps and engineered devices have been strongly advocated as an approach to decreasing percutaneous injury [45]. Increasing regulatory, legislative, and political pressure should increase the use of these devices within hospitals. Further funding is needed for all of these areas of research. Potential approaches to be evaluated could include widespread implementation of programs to better train health care workers and monitor adherence, improved surveillance for and analysis of injury data, and widespread implementation of safer devices where they are most likely to be beneficial.

Acknowledgments

We appreciate the support of the Iowa Department of Public Health, as well as the suggestions of Dr. Larry Murphy and Dr. James Grosch of the National Institute of Occupational Safety and Health, Centers for Disease Control and Prevention, in providing scientific input into the design and conduct of this study. We are indebted to the health care workers who participated in the study for the information they provided.

References

1. Centers for Disease Control and Prevention. Recommendations for prevention of HIV transmission in health-care settings. MMWR Morb Mortal Wkly Rep **1987**; 36(Suppl 2):1S–18S.
2. Centers for Disease Control and Prevention. Guidelines for prevention of transmission of human immunodeficiency virus and hepatitis B virus to health-care and public-safety workers. MMWR Morb Mortal Wkly Rep **1989**; 38(Suppl 6):1–37.
3. Department of Labor. Occupational exposure to bloodborne pathogens, final rule, 56 Federal Register 64004 (1991) (codified at 29 CFR Part 1910.1030:64175–82). Washington, DC: US Government Printing Office, **1991**.
4. Garner JS. Guideline for isolation precautions in hospitals. Infect Control Hosp Epidemiol **1996**; 17:53–80.
5. Occupational Safety and Health Administration (OSHA). Enforcement procedures for the occupational exposure to bloodborne pathogens (codified at 29 CFR 1910.1030). Washington, DC: Department of Labor, **2001**.
6. Beekmann SE, Vaughn TE, McCoy KD, et al. Hospital bloodborne pathogens programs: program characteristics and blood and body fluid exposure rates. Infect Control Hosp Epidemiol **2001**; 22:73–82.
7. McConkey SJ, L'Ecuyer PB, Murphy DM, Leet TL, Sundt TM, Fraser VJ. Results of a comprehensive infection control program for reducing surgical-site infections in coronary artery bypass surgery. Infect Control Hosp Epidemiol **1999**; 20:533–8.

8. McCormick RD, Maki DG. Epidemiology of needle-stick injuries in hospital personnel. Am J Med **1981**; 70:928–32.
9. Ruben FL, Norden CW, Rockwell K, Hruska E. Epidemiology of accidental needle-puncture wounds in hospital workers. Am J Med Sci **1983**; 286:26–30.
10. Linnemann CC, Cannon C, DeRonde M, Lanphear B. Effect of educational programs, rigid sharps containers, and universal precautions on reported needlestick injuries in healthcare workers. Infect Control Hosp Epidemiol **1991**; 12:214–9.
11. McCormick RD, Meisch MG, Ircink FG, Maki DG. Epidemiology of hospital sharps injuries: a 14-year prospective study in the pre-AIDS and AIDS eras. Am J Med **1991**; 91:301S–7S.
12. Whitby M, Stead P, Najman JM. Needlestick injury: impact of a recapping device and an associated education program. Infect Control Hosp Epidemiol **1991**; 12:220–5.
13. Eisenstein HC, Smith DA. Epidemiology of reported sharps injuries in a tertiary care hospital. J Hosp Infect **1992**; 20:271–80.
14. Beekmann SE, Vlahov D, Koziol DE, McShalley ED, Schmitt JM, Henderson DK. Temporal association between implementation of universal precautions and a sustained, progressive decrease in percutaneous exposures to blood. Clin Infect Dis **1994**; 18:562–9.
15. Rattner SL, Norman SA, Berlin JA. Percutaneous injuries on the "front line": a survey of housestaff and nurses. Am J Prev Med **1994**; 10: 372–7.
16. Jackson M, Williams K, Olson-Burgess C, Kinney J, Olson L, Burry VF. Needlestick injuries in a pediatric hospital. Pediatr Infect Dis J **1994**; 13:318–9.
17. Aiken LH, Sloane DM, Klocinski JL. Hospital nurses' occupational exposure to blood: prospective, retrospective, and institutional reports. Am J Public Health **1997**; 87:103–7.
18. Pettit LL, Gee SQ, Begue RE. Epidemiology of sharp object injuries in a children's hospital. Pediatr Infect Dis J **1997**; 16:1019–23.
19. Stotka JL, Wong ES, Williams DS, Stuart CG, Markowitz SM. An analysis of blood and body fluid exposures sustained by house officers, medical students, and nursing personnel on acute-care general medical wards: a prospective study. Infect Control Hosp Epidemiol **1991**; 12: 583–90.
20. Albertoni F, Ippolito G, Petrosillo N, et al. Needlestick injury in hospital personnel: a multicenter survey from central Italy. The Latium Hepatitis B Prevention Group. Infect Control Hosp Epidemiol **1992**; 13: 540–4.
21. National Institute of Occupational Safety and Health (NIOSH). NIOSH alert: preventing needlestick injuries in health care settings. Department of Health and Human Services (DHHS)/NIOSH publication no. 2000-108. Cincinnati: NIOSH, DHHS, Public Health Service, Centers for Disease Control and Prevention, **1999**.
22. Norcross JC, Carlo C. Factor structure of the Levels of Attribution and Change (LAC) Scale in samples of psychotherapists and smokers. J Clin Psychol **1984**; 40:519–28.
23. Zwerling C, Sprince NL, Wallace RB, et al. Effect of recall period on the reporting of occupational injuries among older workers in the Health and Retirement Study. Am J Ind Med **1995**; 28:583–90.
24. Diekema DJ, Albanese MA, Schuldt SS, Doebbeling BN. Blood and body fluid exposures during clinical training: relation to universal precautions knowledge. J Gen Intern Med **1996**; 11:109–11.
25. Centers for Disease Control and Prevention. Recommendations for preventing transmission of human immunodeficiency virus and hepatitis B virus to patients during exposure-prone invasive procedures. MMWR Morb Mortal Wkly Rep **1991**; 40(RR-8):1–9.
26. Kanuk L, Berenson C. Mail surveys and response rates: a literature review. J Mark Res **1975**; 7:440–53.
27. Hoddinott S, Bass M. The Dillman total design survey method: a surefire way to get high survey return rates. Can Fam Physician **1986**; 32: 2366–8.
28. Shiono P, Klebanoff M. The effect of two mailing strategies on the response to a survey of physicians. Am J Epidemiol **1991**; 134:539–42.
29. Campbell MJ, Waters WE. Does anonymity increase response rate in postal questionnaire surveys about sensitive subjects? A randomised trial. J Epidemiol Community Health **1990**; 44:75–6.
30. Fox RJ, Crask MR, Kim J. Mail survey response rate: a meta-analysis of selected techniques for inducing response. Public Opin Q **1988**; 52: 467–91.
31. Choi BC, Pak AWP, Purdham JT. Effects of mailing strategies on response rate, response time, and cost in a questionnaire study among nurses. Epidemiology **1990**; 1:72–4.
32. Hersey JC, Martin LS. Use of infection control guidelines by workers in healthcare facilities to prevent occupational transmission of HBV and HIV: results from a national survey. Infect Control Hosp Epidemiol **1994**; 15:243–52.
33. Saghafi L, Raselli P, Francillon C, Francioli P. Exposure to blood during various procedures: results of two surveys before and after the implementation of universal precautions. Am J Infect Control **1992**; 20:53–7.
34. Henry K, Campbell S, Maki M. A comparison of observed and self-reported compliance with universal precautions among emergency department personnel at a Minnesota public teaching hospital: implications for assessing infection control programs. Ann Emerg Med **1992**; 21:940–6.
35. Doebbeling BN, Stanley GL, Sheetz CT, et al. Comparative efficacy of alternative handwashing agents in reducing nosocomial infection rates in intensive care units. N Engl J Med **1992**; 327:88–93.
36. Nelsing S, Nielsen TL, Nielsen JO. Percutaneous blood exposure among Danish doctors: exposure mechanisms and strategies for prevention. Eur J Epidemiol **1997**; 13:387–93.
37. Tan L, Hawk JC 3rd, Sterling ML. Report of the Council on Scientific Affairs: preventing needlestick injuries in health care settings. Arch Intern Med **2001**; 161:929–36.
38. Centers for Disease Control and Prevention. Evaluation of safety devices for preventing percutaneous injuries among health-care workers during phlebotomy procedures—Minneapolis–St. Paul, New York City, and San Francisco, 1993–1995. MMWR Morb Mortal Wkly Rep **1997**; 46:21–5.
39. Beekmann SE, McCoy KD, Vaughn TE, et al. Standard precautions, training rates, mucocutaneous exposures and sharps injury rates by occupation [abstract 295]. In: Abstracts of the Society for Healthcare Epidemiology of America 9th Annual Meeting (San Francisco). Thorofare, NJ: Slack, Inc., **1999**:554.
40. Gershon RRM, Pearse L, Grimes M, Flanagan PA, Vlahov D. The impact of multifocused interventions on sharps injury at an acute-care hospital. Infect Control Hosp Epidemiol **1999**; 20:806–11.
41. Gershon RRM, Vlahov D, Felknor SA, et al. Compliance with universal precautions among health care workers at three regional hospitals. Am J Infect Control **1995**; 23:225–36.
42. Michalsen A, Delclos GL, Felknor SA, et al. Compliance with universal precautions among physicians. J Occup Environ Med **1997**; 39:130–7.
43. Murphy L, Sturdivant K, Gershon R. Organizational and employee characteristics predict compliance with universal precautions. Presented at: 5th Annual American Psychological Society Convention (25–28 June 1993, Chicago).
44. Clarke SP, Sloane DM, Aiken LH. Effects of hospital staffing and organizational climate on needlestick injuries to nurses. Am J Public Health **2002**; 92:1115–9.
45. Jagger J, Pearson RD. Universal precautions: still missing the point on needlesticks. Infect Control Hosp Epidemiol **1991**; 12:211–3.