ORIGINAL ARTICLE

Use of Gloves and Reduction of Risk of Injury Caused by Needles or Sharp Medical Devices in Healthcare Workers: Results from a Case-Crossover Study

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OBJECTIVE. Standard precautions are advocated for reducing the number of injuries caused by needles and sharp medical devices ("sharps injuries"), but the effectiveness of gloves in preventing such injuries has not been established. We evaluated factors associated with gloving practices and identified associations between gloving practices and sharps-injury risk.

DESIGN. Usual-frequency case-crossover study.

SETTING. Thirteen medical centers in the United States and Canada.

PARTICIPANTS. Six hundred thirty-six healthcare workers who presented to employee health clinics after sharps injury.

METHODS. Structured telephone questionnaires were administered to assess usual behaviors and circumstances at the time of injury.

RESULTS. Of 636 injured healthcare workers, 195 were scrubbed in an operating room or procedure suite when injured, and 441 were injured elsewhere. Nonscrubbed individuals were more commonly gloved when treating patients who were perceived to have a high risk of human immunodeficiency virus, hepatitis B virus, or hepatitis C virus infection than when treating other patients (adjusted odds ratio [aOR], 2.53 [95% confidence interval {CI}, 1.30–4.91]). Nurses (aOR, 0.11 [95% CI, 0.04–0.32]) and other employees (aOR, 0.24 [95% CI, 0.07–0.77]) were less commonly gloved at injury than were physicians and physician trainees. Gloves reduced injury risk in case-crossover analyses (incidence rate ratio [IRR], 0.33 [95% CI, 0.22–0.50]). In scrubbed individuals, involvement in an orthopedic procedure was associated with double gloving at injury (aOR, 13.7 [95% CI, 4.55–41.3]); this gloving practice was associated with decreased injury risk (IRR, 0.20 [95% CI, 0.10–0.42]).

CONCLUSIONS. Although the use of gloves reduces the risk of sharps injuries in health care, use among healthcare workers is inconsistent and may be influenced by risk perception and healthcare culture. Glove use should be emphasized as a key element of multimodal sharps-injury reduction programs.

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Injuries caused by needles and sharp medical devices ("sharps injuries") represent an important source of morbidity and economic costs in the healthcare environment. It is estimated that 600,000–800,000 such injuries are reported annually in the United States, with a direct financial burden of $500 million.[1-4] Indirect costs, including those related to absenteeism and distress on the part of affected healthcare workers (HCWs), are also likely to be substantial; given the known risk of hepatitis B virus, hepatitis C virus, and human immunodeficiency virus (HIV) transmission, sharps injuries are often accompanied by a considerable and long-lasting emotional impact.[2,5-7]

To protect personnel from pathogens transmitted in the healthcare environment, "standard precautions" have been advocated by the Centers for Disease Control and Prevention and regulated by the Occupational Safety and Health Administration.[8-10] These measures include proper hand hygiene, appropriate disposal of sharp devices, and the use of personal protective equipment. Latex or vinyl gloves, in particular, form an important component of precautions. Gloving appears to reduce risk to HCWs by protecting against incident bloodborne infection following injury with a contaminated sharp device and by lessening the inoculum of blood introduced by injury, particularly when injury is caused by hollow-

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bore needles.[11-13] However, the question of whether glove use is associated with reduced risk of injury remains unresolved.

Commonly used gloves are sufficiently thin to provide little protection from penetrating skin trauma by a sharp piece of metal, bone, or glass.[14,15] Few estimates are available for their effectiveness in injury reduction outside operating rooms (ORs).[16,17] In surgical settings, wearing 2 pairs of gloves to provide an additional barrier is becoming more common, particularly in orthopedic and dental procedures.[18] Evidence suggests that this practice is associated with a reduced risk of glove perforation, compared with the risk associated with the use of a single pair of gloves.[18] Nevertheless, there remains a perception among some HCWs that double gloving may reduce manual dexterity to an extent that makes accidental puncture and percutaneous injury more likely.[19-22]

Because of the extremely large number of personnel at risk of sharps injury (an estimated 5.6 million individuals in the United States[23]), even a small enhancement or reduction in injury risk by glove use would have important health consequences. Given that neither single nor double gloving is ubiquitous,[18,19,24,25] we sought to identify factors associated with each of these practices among HCWs. A second objective was to evaluate the effectiveness of gloving and double gloving in protecting against sharps injuries, using a case-crossover approach. This study design, which evaluates associations between transient exposures and acute events, has been used previously to identify risk factors for injuries both in the healthcare environment[26,27] and in other settings.[28-33]

METHODS

Study Population

Subject recruitment has been described in detail elsewhere.[26,27] Briefly, subjects were HCWs who presented to employee health clinics at 13 medical centers after injury by sharp medical devices. Individuals were considered to be ineligible if they had been injured by a clean device not yet used for patient care or if they had sustained only a skin or mucus membrane splash without skin puncture or laceration. Participating centers were university-affiliated hospitals located in 4 cities: Baltimore, Maryland ($n = 6$); Boston, Massachusetts ($n = 3$); Salt Lake City, Utah ($n = 1$); and Toronto, Ontario, Canada ($n = 3$). The study protocol was approved by the review board of each institution, and written informed consent was obtained from all subjects at the time of post-exposure risk assessment.

Interview

Eligible consenting HCWs were interviewed using a standardized questionnaire administered over the telephone by trained interviewers. The median time elapsed between date of injury and completion of the study questionnaire was 3 days (range, 0–15 days); 626 participants (98%) were contacted within a week of assessment in employee health services.

For all subjects, information was collected on demographic characteristics, job description, experience in present occupation, circumstances surrounding injury, and usual behaviors (including usual patterns of glove and double-glove use while at risk of sharps injury). The structure and phrasing of questions related to gloving can be found in Appendix A, Figure A1.

Study Design

The case-crossover study is an observational design that uses self-matching, rather than an external group, in obtaining control data.[34,35] Such an approach allows for the evaluation of relationships between brief, transient exposures and an acute event, while inherently controlling for factors that might confound the results of a traditional case-control study. It may be thought of as analogous to a matched case-control design, in which cases and controls are matched for all characteristics that remain constant over the study period (eg, sex and job description).

A "usual frequency" case-crossover approach was used, such that the presence of exposure during the hazard period (ie, gloving or double-gloving at injury) was evaluated in the context of usual frequency of exposure while at risk of sharps injury. We distinguished between individuals who sustained their injuries while scrubbed in an OR or procedure suite and those injured while not scrubbed in an OR or procedure suite. The former group was considered to have been working in a setting of continual risk; the number of hours spent scrubbed in the week before injury was taken as the total time at risk of sharps injury. The latter group was deemed to be at noncontinual risk, with time at risk calculated as the product of the number of procedures performed in the previous month and the mean time required to complete a procedure. Estimates of time at risk have been found to be highly reliable in this context[26]: in 40 subjects participating in the pilot phase of the study who were reinterviewed from 2 to 5 days after initial completion of the questionnaire, the intraclass correlation coefficient for total time at risk of sharps injury was 0.96 (95% confidence interval [CI], 0.93–0.98). Usual frequencies of exposures were estimated as the proportion of time that a subject experienced a specified exposure while at risk of sharps injury.

Statistical Analysis

Characteristics of individuals gloved at injury and those of individuals ungloved at injury were compared using χ^2 tests for categorical variables and the Wilcoxon rank-sum test for continuous variables. Factors found to be significantly ($P < .05$) associated with glove use in bivariable analyses were entered into a stepwise selection algorithm, with variables entered into and retained in the multivariable model for

TABLE 1. Characteristics of 636 Healthcare Workers Who Presented to Employee Health Clinics after Injury Caused by a Needle or Sharp Medical Device

Characteristic	All subjects (n = 636)	Individuals scrubbed at time of injury (n = 195)	Individuals not scrubbed at time of injury (n = 441)
Age, median (IQR)[a]	31 (27–39)	32 (28–40)	30 (26–39)
Female sex	405 (64)	92 (47)	313 (71)
Ethnicity			
Asian American	70 (11)	24 (12)	46 (10)
Black	74 (12)	18 (9)	56 (13)
White	458 (72)	144 (74)	314 (71)
Other	34 (5)	9 (5)	25 (6)
Job description[a]			
Physician or physician trainee	243 (38)	106 (54)	137 (31)
Nurse or nursing trainee	248 (39)	40 (21)	208 (47)
Other	144 (23)	49 (25)	95 (22)
Years of experience, median (IQR)[b]	3 (1–7)	4 (2–6)	3 (1–8)
Location where injury occurred[a]			
Emergency department	40 (6)	...	40 (9)
Intensive care unit	57 (9)	...	57 (13)
Patient room	143 (23)	...	143 (33)
Other[c]	395 (62)	195 (100)	200 (45)
Emergency situation at injury	66 (10)	21 (11)	45 (10)
Device that caused injury			
Hollow-bore needle	322 (51)	36 (18)	286 (65)
Scalpel or blade	59 (9)	26 (13)	33 (7)
Solid-bore needle	143 (22)	97 (50)	46 (10)
Stylette or trocar	33 (5)	3 (2)	30 (7)
Other	79 (12)	33 (17)	46 (10)
High-risk exposure[b,d]	241 (38)	75 (39)	166 (38)
History of prior sharps injuries[a]	370 (58)	147 (75)	223 (51)
No. of past injuries, median (IQR)[e]	1 (0–3)	2 (1–5)	1 (0–2)
Percent of past injuries reported, median (IQR)[f]	50 (1–100)	50 (14–100)	50 (0–100)

NOTE. Data are no. (%) of healthcare workers in the category, unless otherwise indicated. Percentages may not add to 100 because of rounding. IQR, interquartile range.
[a] Information missing for 1 individual not scrubbed at time of injury.
[b] Information not available for 8 participants (5 individuals scrubbed at time of injury and 3 individuals not scrubbed at injury).
[c] Includes operating rooms and procedure suites.
[d] Source patient known or believed by healthcare worker to be infected with human immunodeficiency virus, hepatitis B virus, or hepatitis C virus.
[e] Information not available for 5 participants (1 individual scrubbed at time of injury and 4 individuals not scrubbed at time of injury).
[f] Among individuals reporting at least 1 previous sharps injury (information missing for 1 individual scrubbed at injury and 3 individuals not scrubbed at time of injury).

$P < .05$. Characteristics and circumstances associated with double gloving at injury were identified in a similar manner.

In case-crossover analyses, usual-frequency estimates were used to calculate the amount of person-time spent gloved and double gloved during the previous month (for those not scrubbed in an OR or procedure suite at injury) or during the previous week (for those scrubbed at injury). Unexposed person-time was calculated as the difference between total time at risk and exposed person-time. Data were analyzed using standard methods for highly stratified data, in which the individual subject is the stratifying variable.[34,36] Methods for estimation of incidence rate ratios (IRRs) using a usual-frequency case-crossover approach are described in greater detail in Appendix B.

The contribution of nonuse of gloves or nonuse of double gloves to sharps-related injury burden was quantified using population-attributable risk percent calculations.[37] Excess fractions represent the proportion of injuries expected not to occur if gloving and double gloving were universal among HCWs. Because these values depend not only on the strength of association between an exposure and outcome but also on the prevalence of exposure in a population, we calculated excess fractions across a range of gloving and double-gloving frequencies. Results should be interpreted in light of usual

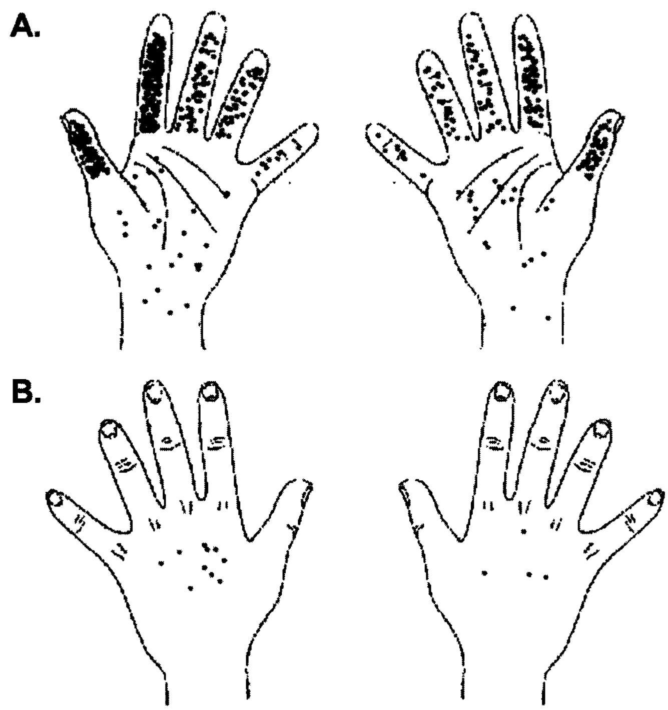

FIGURE 1. Distribution of injuries caused by needles and sharp medical devices on the hands and wrists. Dots represent injuries to the palm (*A*) and dorsum (*B*) of the hand. Sites on the forearm ($n = 2$) and chest ($n = 1$) are not shown.

frequency of glove and double-glove use while at risk of sharps-related injury. All statistical analyses were performed using SAS, version 9.1 (SAS).

RESULTS

A total of 636 HCWs were interviewed from February 1, 2000, through June 30, 2006. Of these, 195 reported having been scrubbed in an OR or procedure suite at the time of injury, and the remaining 441 individuals were not scrubbed at injury. The median age of all participants was 31 years, and the majority of HCWs were female. Most injuries were caused by a hollow-bore needle. Solid-bore needles, scalpels, blades, stylettes, and trocars were also frequently associated with injury (Table 1). The most commonly affected sites were the thumb, index finger, and middle finger (Figure 1), with 66% of individuals injured on their nondominant hand. Right-handed HCWs were found to be significantly more likely than their left-handed counterparts to sustain an injury on the left hand (adjusted odds ratio [aOR], 2.85 [95% CI, 1.53–5.33]).

Factors Associated with Glove Use among HCWs

All subjects scrubbed in an OR or procedure suite wore gloves at the time of injury. Among nonscrubbed HCWs for whom information was available ($n = 427$), 359 (84%) reported wearing gloves at injury and 68 (16%) were ungloved at injury (Table 2). In bivariable analysis, individuals gloved at injury were more likely than those not gloved at injury to be male, in training (ie, a resident or student), dealing with an emergency situation, and treating a patient perceived to be high risk (ie, infected or believed to be infected with HIV, hepatitis B virus, or hepatitis C virus). Individuals not using gloves at the time of injury were significantly more likely to report a history of formal safety training ($P = .04$). An association between job description and glove use was also identified, with nurses less likely and physicians more likely to have been gloved. In multivariable analysis, perceived high-risk patient status (aOR, 2.53 [95% CI, 1.30–4.91]) was an independent predictor of glove use at injury, and nurses (aOR, 0.11 [95% CI, 0.04–0.32]) and other employees (eg, technicians) (aOR, 0.24 [95% CI, 0.07–0.77]) were less likely to have been wearing gloves than were physicians and physician trainees.

Factors Associated with Use of Double Gloves among HCWs

Among HCWs not scrubbed at time of injury, 12 (3%) were double gloved. The majority of these individuals were white ($n = 9$), were not in training ($n = 9$), and had a history of prior sharps injury ($n = 8$). In 195 HCWs who were scrubbed in an OR or procedure suite at injury, information on double-glove use was available for 193 subjects (99%). Of these, 83 (43%) reported use of double gloves at the time of their sharps injury. Numerous worker and task characteristics, including job description, sharp device responsible for injury, perceived high-risk exposure, involvement in an orthopedic procedure,

TABLE 2. Characteristics of Healthcare Workers Not Scrubbed in an Operating Room or Procedure Suite, According to Glove Use at Time of Injury Caused by a Needle or Sharp Medical Device

Characteristic	Gloved at time of injury (n = 359)	Not gloved at time of injury (n = 68)	P
Age, median (IQR)[a]	30 (26–39)	30 (26–40)	.89
Female sex	248 (69)	56 (82)	.03
Ethnicity			.06
Asian American	36 (10)	8 (12)	
Black	54 (15)	2 (3)	
White	250 (70)	53 (78)	
Other	19 (5)	5 (7)	
Job description[a]			<.001
Physician or physician trainee	124 (35)	4 (6)	
Nurse or nursing trainee	155 (43)	52 (76)	
Other	79 (22)	12 (18)	
Trainee[a]	119 (33)	4 (6)	<.001
Years of experience, median (IQR)[b]	3 (1–7)	4 (1–10)	.37
Location where injury occurred[a]			.08
Emergency department	37 (10)	3 (4)	
Intensive care unit	50 (14)	7 (10)	
Patient room	111 (31)	31 (46)	
Other	160 (45)	27 (40)	
Emergency situation at injury	42 (12)	1 (1)	.01
Device that caused injury			.07
Hollow-bore needle	231 (64)	52 (76)	
Scalpel or blade	23 (6)	4 (6)	
Solid-bore needle	44 (12)	1 (1)	
Stylette or trocar	27 (8)	3 (4)	
Other	34 (9)	8 (12)	
High-risk exposure[c,d]	145 (41)	15 (22)	.01
History of formal safety training[e]	229 (71)	54 (83)	.04
History of sharps injuries	179 (50)	35 (51)	.81
Number of previous sharps injuries, median (IQR)[b]	0 (0–2)	1 (0–2)	.94

NOTE. Data are no. (%) of healthcare workers in the category, unless otherwise indicated. Percentages may not add up to 100 because of rounding. IQR, interquartile range.
[a] Information missing for 1 individual.
[b] Information missing for 3 individuals.
[c] Information not available for 2 individuals.
[d] Source patient known or believed by healthcare worker to be infected with human immunodeficiency virus, hepatitis B virus, or hepatitis C virus.
[e] Information not available for 39 individuals.

and procedure duration, were associated with the likelihood of double gloving in bivariable analyses (Table 3). However, in a multivariable analysis, only involvement in an orthopedic procedure was independently associated with double gloving at injury (aOR, 13.7 [95% CI, 4.55–41.3]).

Risk of Sharps Injury and Its Association with Gloving and Double Gloving

Among nonscrubbed HCWs, gloves were worn less frequently at injury than would be expected on the basis of estimates of usual-exposure frequency (Figure 2*A*). In case-crossover analyses, glove use was associated with a significant decrease in injury risk (IRR, 0.33 [95% CI, 0.22–0.50]). This association persisted in a restriction analysis to evaluate single gloving relative to nongloving, in which individuals wearing double gloves were excluded (IRR, 0.32 [95% CI, 0.21–0.48]). Stratified analyses were performed to determine whether the overall effect of gloving was modified by experience (time in occupation at least 5 years vs time in occupation less than 5 years), sex, status as a trainee, or job description (nurse or nursing trainee vs nonnurse). The protective relationship between gloving and sharps-related injury risk was found to be greater in nontrainees than in trainees (IRR, 0.25 [95% CI, 0.16–0.40] vs 1.76 [95% CI, 0.55–5.64]; P = .002 for heterogeneity). A similar effect was seen for nurses and nursing trainees relative to physicians and individuals in other occupations (IRR, 0.25 [95% CI, 0.15–0.41] vs 0.69 [95% CI, 0.34–1.39]; P = .02 for heterogeneity). The protection af-

TABLE 3. Characteristics of Healthcare Workers Scrubbed in an Operating Room or Procedure, According to Double-Glove Use at Time of Injury Caused by a Needle or Sharp Medical Device

Characteristic	Double gloved at time of injury (n = 83)	Not double gloved at time of injury (n = 110)	P
Age, median (IQR)	31 (28–40)	32 (29–40)	.57
Female sex	43 (52)	48 (44)	.26
Ethnicity			.52
Asian American	8 (10)	14 (13)	
Black	10 (12)	8 (7)	
White	60 (72)	84 (76)	
Other	5 (6)	4 (4)	
Job description			.02
Physician or physician trainee	35 (42)	69 (63)	
Nurse or nursing trainee	21 (25)	19 (17)	
Other	27 (33)	22 (20)	
Trainee	33 (40)	56 (51)	.12
Years of experience, median (IQR)[a]	4 (2–6)	4 (2–6)	.34
Procedure duration, hours, median (IQR)[b]	3 (2–5)	2 (1–4)	.003
Orthopedic procedure	30 (36)	4 (4)	<.001
Emergency situation at injury	11 (13)	9 (8)	.25
Device that caused injury			.01
Hollow-bore needle	9 (11)	27 (25)	
Scalpel or blade	9 (11)	17 (15)	
Solid-bore needle	44 (53)	52 (47)	
Stylette or trocar	0 (0)	3 (3)	
Other	21 (25)	11 (10)	
High-risk exposure[a,c]	39 (48)	34 (32)	.02
History of sharps injuries	62 (75)	83 (75)	.90
Number of previous sharps injuries, median (IQR)[d]	2 (0–5)	2 (1–5)	.95

NOTE. Data are no. (%) of healthcare workers in the category, unless otherwise indicated. Percentages may not add up to 100 because of rounding. IQR, interquartile range.
[a] Information missing for 5 individuals.
[b] Information not available for 14 individuals.
[c] Source patient known or believed by healthcare worker to be infected with human immunodeficiency virus, hepatitis B virus, or hepatitis C virus.
[d] Information not available for 1 individual.

forded by wearing gloves was not modified by sex (P = .62) or experience (P = .56) of the HCW.

In scrubbed individuals, there was variation between the prevalence of double gloving at injury and the usual frequency of double gloving. As presented in Figure 2*B*, exposure at time of injury was substantially less common than expected. Case-crossover analyses confirmed the protective association between double gloving and risk of sharps-related injury (IRR, 0.20 [95% CI, 0.10–0.42]). This relationship was not modified by sex (P = .92), experience (P = .75), trainee status (P = .67), or job description (P = .64).

Excess Fractions Attributable to Nonuse of Gloves or Nonuse of Double Gloves

Excess fractions of injury attributable to nongloving among HCWs who were not scrubbed in an OR or procedure suite were calculated as described in Methods. Under the assumption of a constant relative risk, the excess fraction of sharps injuries would increase as gloving became less common (Figure 3*A*). On the basis of the mean frequency of nongloving in this study (12%), approximately 19% of sharps injuries would not have occurred in this subpopulation of HCWs if gloving were universal.

Among HCWs scrubbed in an OR or procedure suite, the mean frequency of not double gloving was 50%. Therefore, 66% of injuries would be expected to have not occurred if double gloving had been uniformly and universally practiced in this setting (Figure 3*B*).

DISCUSSION

In this study, a case-crossover design was used to evaluate the relationship between gloving practices and risk of injury related to needles and sharp medical devices, distinguishing between HCWs scrubbed in an OR or procedure suite and those outside of the surgical environment. We found that among personnel not scrubbed at time of injury, glove use was associated with a significant reduction in risk. Results of

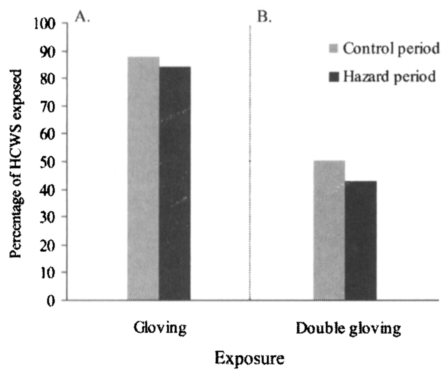

FIGURE 2. Frequency of exposure to risk of injuries caused by needles and sharp medical devices during hazard and control periods. *Black bars* represent the proportion of healthcare workers who reported having been exposed during the hazard period (ie, at injury). *Gray bars* represent the mean frequency of exposure during the control period ("usual frequency"). Analyses of gloving (*A*) were restricted to individuals not scrubbed in an operating room or procedure suite at injury. Evaluation of double gloving (*B*) was restricted to individuals who were scrubbed at the time of injury. Relative risks were calculated using stratified analyses and therefore cannot be approximated directly from comparison of exposure frequencies in the hazard and control periods.

a restriction analysis suggest that this effect was not attributable to the use of double gloves among a small subset of subjects but rather to the use of single gloves relative to nongloving. In healthcare personnel who were scrubbed in a sterile environment at injury, a protective association was identified between double gloving and risk of injury. This finding appears to refute the belief that using 2 pairs of gloves may compromise tactility and dexterity and paradoxically may result in an increased likelihood of percutaneous puncture. It is also consistent with the conclusions of numerous randomized, controlled trials that have shown the use of 2 pairs of gloves to be more effective than the use of a single pair of gloves in reducing perforations during surgical procedures (with glove perforation serving as a surrogate for injury end points).[18]

Randomized trials to evaluate the effect of gloving on sharps injury risk outside the OR have not been performed, for obvious logistic and ethical reasons (ie, universal glove use is prescribed, given the well-accepted benefits of gloving in protecting HCWs from disease transmission[8]). In the absence of such experimental epidemiologic evidence, observational studies will be vulnerable to criticism that findings are subject to uncontrolled confounding. However, the self-matching characteristic of the case-crossover study design makes it unlikely that our results were confounded by job description, experience with procedures, or time at risk of injury. It should also be noted that, regardless of whether glove use outside the surgical setting is causally associated with a decrease in injury risk, it may have value as an important index of general safety practices and vigilance against occupational hazards.

Our findings about gloving behaviors indicate that such safety practices are not universally implemented among HCWs, despite mandated use of standard precautions in all risk settings and the protection afforded by personal protective equipment. In personnel not scrubbed at injury, the mean frequency of nonuse of gloves was 12%. Individuals who were treating a patient perceived to be low risk (ie, not believed to be infected with hepatitis B virus, hepatitis C virus, or HIV) were less likely to be gloved at injury than were individuals who were treating a patient perceived to be high risk. Also, nurses and other personnel were less likely to be gloved at injury than were physicians. HCWs scrubbed in an OR or procedure suite were double gloved for a mean of 50% of the time at risk of sharps injury. Individuals involved in nonorthopedic procedures at the moment of injury were significantly less likely to have been double gloved at the time of injury. This is consistent with prior observations showing that the majority of orthopedic surgeons in the United States use protection beyond single gloves (eg, double gloves, glove lin-

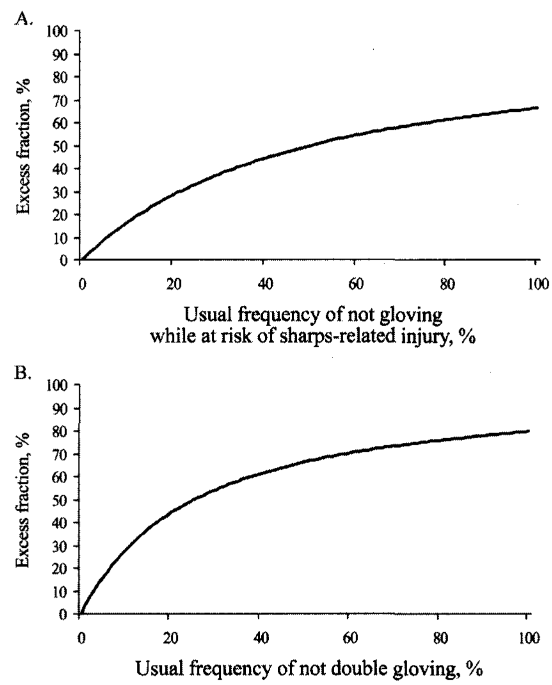

FIGURE 3. Excess fraction of injuries caused by needles and sharp medical devices attributable to not gloving (*A*) and to not double gloving (*B*) while at risk, with varying frequency of exposure. Estimates for not gloving are based on the assumption of a constant relative risk (2.99) among healthcare workers not scrubbed at the time of injury (ie, in a setting of noncontinual risk). The curve for not double gloving is based on a relative risk of 4.94 among individuals scrubbed in an operating room or procedure suite at injury (ie, in a setting of continual risk).

ers, and cloth outer gloves), whereas surgeons in other specialties do not routinely use double gloves.[18,19,38]

Therefore, it would appear that gloving practices are based not on innate personal characteristics but on factors related to risk perception and healthcare culture. On the basis of this evidence, efforts to increase the routine wearing of gloves or double gloves might focus on surgical and occupational groups, particularly nurses and nonorthopedic surgeons, in combination with other complementary strategies, such as enhancing the safety of sharp devices and reducing the unnecessary use of sharp devices.[39] Given the apparent benefit of gloving in reducing the risk of sharps injury—a finding that we believe is plausible and robust—these types of efforts may have important health and health-economic consequences. We found that nursing and nontrainee healthcare personnel appear to benefit most from glove use in a nonsurgical setting, suggesting that the impact in those groups might be especially useful.

There are, however, limitations to this study that ought to be recognized in evaluating the apparent protective benefits of gloving. As in any epidemiologic investigation that involves the collection of retrospective data, recall of past gloving exposures may have been inaccurate. Subjects' estimates were not validated through either direct observation of gloving practices or evaluation of reproducibility. However, results would be vulnerable to recall bias only if misclassification of exposure status occurred differentially with respect to status at time of injury and usual frequency of exposure. Because the same individuals assessed both "case" and "control" behaviors, this seems less likely than would be expected with either a case-control or cohort design. Furthermore, use of gloves and double gloves might be less susceptible to biased reporting, compared with the susceptibility of other factors (such as emotional state at time of injury), because of its more objective nature. We were able to recruit for the study only individuals who reported their injuries to participating employee health services, which may limit the generalizability of our results. However, we have no reason to expect differences in glove effects on the basis of propensity to report injuries.

The issue of case-selection bias in this study may be more problematic, in particular with respect to the possibility of preferential reporting of injuries sustained when working with patients perceived to be "high risk" for transmission of bloodborne pathogens. If workers were more likely to use gloves or more likely to double-glove with high-risk patients, and if they were more likely to report injuries sustained while working with these patients, this would have enriched the prevalence of glove or double-glove use in the hazard period, which in turn would have biased our estimates of glove effectiveness toward the null. As such, inasmuch as case-selection bias could have occurred in this study, our effect estimates should be regarded as lower-bound estimates.

The known underreporting of sharps injuries[2,40-43] introduces the possibility of a second limitation to this study—selection bias, which may have occurred if gloved or double-gloved workers were less likely to report injuries than their counterparts. This is conceivable, given that incidents that occurred while using barrier precautions might be perceived as less serious; however, one could also posit that individuals gloved at injury are in fact more likely to report than their colleagues, who might fear sanction because of nonadherence to hospital policies. It is difficult to predict with any certainty which possibility is more likely without a complete understanding of the complex and possibly institution-specific factors that influence reporting. Insight into such factors might be informative not only in evaluating the likelihood of bias in the present study but also, more broadly, in attempts to increase disclosure of sharps injuries.

In summary, we have shown that gloving and double gloving are associated with reduced risk of injury by needles and other sharp medical devices. Despite their apparent benefits, these practices are not ubiquitous and may be an important target in reducing the burden of sharps injuries—a significant cause of morbidity and economic costs in the healthcare environment.

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APPENDIX A.

For injury in a setting of non-continuous risk (i.e., healthcare worker not scrubbed in an operating room or procedure suite at time of injury):

Were you wearing gloves at the time you were injured?
Yes No

In the past month, how often did you wear gloves while performing *task*?
_____ times

Were you double-gloved at the time you were injured?
Yes No

In the past month, how often were you double-gloved while performing *task*?
_____ times

For injury in a setting of continuous risk (i.e., healthcare worker scrubbed in an operating room or procedure suite at time of injury):

Did you double-glove on the day of your injury?
Yes No

If yes, then ask:
Were you double-gloved at the time of your injury?
Yes No

What percent of time, over the past week, have you been double-gloved while scrubbed in the O.R. or procedure suite?
_____ %

FIGURE A1. Sample questions related to glove and double-glove use in healthcare workers.

APPENDIX B.

USUAL-FREQUENCY CASE-CROSSOVER ANALYSIS

Usual-frequency estimates were used to calculate the amount of person-time spent gloved and double-gloved during the previous month (for those not scrubbed in an OR or procedure suite at injury) or during the past week (for those scrubbed at injury). Unexposed person-time was calculated as the difference between total time at risk and exposed person-time. IRRs (as a measure of relative risk) and corresponding 95% CIs were estimated using the Mantel-Haenszel estimator for person-time data in which the individual subject is the stratifying variable,[34,36,44] with standard methods used to compute variance.[45]

Briefly, the IRR under this approach is estimated in the following formula:

$$\mathrm{IRR} = \Sigma(a_i N_{0i}/T_{+i})/\Sigma(b_i N_{1i}/T_{+i}) \ .$$

Here, T_{+i} represents total person-time at risk in the ith injured subject; a_i and b_i are binary variables representing exposure (glove) status (exposed and unexposed, respectively) at the time of injury. N_{1i} and N_{0i} represent exposed (gloved) and unexposed (ungloved) person-time while at risk, respectively. For example, an individual who had 90 minutes of time at risk of injury over the past month, who spent 50% of that time gloved, and who was gloved at the time of injury, would contribute $1 \times 45/90 = 0.5$ to the numerator of the IRR, and $0 \times 45/90$ to the denominator. Individuals who either are always exposed or are never exposed contribute no information to the estimator. By contrast, individuals who almost always wear gloves but who are ungloved at injury would contribute maximally to the denominator; those who seldom wear gloves but who are gloved at injury would contribute maximally to the numerator.

Modification of the effect of both gloving and double gloving by third variables was explored through stratification, with evidence of heterogeneity assessed using the χ^2 test.[44]

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