Management Practices and Risk of Occupational Blood Exposure in U.S. Paramedics: Needlesticks

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Background *The purpose of this study was to present risk estimates for needlestick in U.S. paramedics and estimated risk ratios for selected management practices.*
Methods *A mail survey was conducted among a national sample of U.S. paramedics in 2002–2003.*
Results *The adjusted response rate was 55% (n = 2,664). The overall 12-month risk of needlestick was 6.7% (95% confidence interval, 5.4–7.9). Risk ratios for provision of safety-engineered medical devices and two supervisory behaviors that emphasized safe work practices ranged from 2.5 to 3.2. The protective effect of working in an environment that included both of the supervisory behaviors was greater than the protective effect of always being provided with safety devices. A sensitivity analysis indicated that the risk ratio estimates were unlikely to be inflated by nonresponse bias.*
Conclusions *These results suggest that greater provision of safety devices and interventions aimed at management practices that promote worker safety could substantially reduce the risk of needlestick among U.S. paramedics.* Am. J. Ind. Med. 2010. © *2010 Wiley-Liss, Inc.*

KEY WORDS: needlestick; paramedic; blood exposure; occupational exposure; prehospital; risk; safety; survey

INTRODUCTION

Paramedics work under conditions that are conducive to being stuck with a needle after it has been used on a patient [Peate, 2001]. These conditions include performing medical procedures in moving vehicles and attending to uncooperative or combative patients in unstructured settings [Leiss et al., 2009]. As a result, paramedics in the U.S. experience an estimated 10,000 needlesticks a year [Leiss et al., 2006]. Exposure to patient blood through needlesticks puts paramedics at risk of infection with bloodborne pathogens, including human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV) [Centers for Disease Control and Prevention, 1989, 2001].

Two primary approaches have been developed to reduce health care workers' risk of needlestick. One is following Universal Precautions, a set of guidelines recommended by the Centers for Disease Control and Prevention that includes measures for preventing needlesticks through proper handling and disposal of needles and medical devices containing needles [Centers for Disease Control and Prevention, 1987, 1988; Garner, 1996]. The second is providing workers with safety-engineered medical devices that are designed to reduce the risk of needlestick [Tuma and Sepkowitz, 2006; Occupational Safety and Health Administration, 2007a; Whitby et al., 2008]. In addition, various aspects of the work environment [Clarke et al., 2002b; Lymer et al., 2004], including structural and psychosocial factors and available resources, may be important determinants of the extent to which following Universal Precautions and using safety devices reduce workers' risk of needlesticks [Gershon et al., 1995; Vaughn et al., 2004; Adams and Elliott, 2006].

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Little is known about factors associated with risk of needlestick among paramedics. Most previous research examined hospital workers, whose risk and risk factors may differ from those of paramedics [Chen and Jenkins, 2007]. The purpose of this report is to present updated risk estimates for needlestick in U.S. paramedics and estimated risk ratios for selected risk factors, with a focus on management practices.

MATERIALS AND METHODS

The National Study to Prevent Blood Exposure in Paramedics was a mail survey conducted during 2002–2003 among a national sample of licensed paramedics in the U.S. Eligibility criteria were holding current certification/licensure as a paramedic, currently working (paid or volunteer) as a paramedic responding to calls in an emergency vehicle, and having responded to four or more calls in the previous 4 weeks. These criteria were intended to select participants who were currently engaged in delivering paramedic care to patients, as opposed to administrative tasks or training. A two-stage probability sample (n = 6,500) was selected, with states as the first stage and paramedics (from lists provided by the selected states) as the second stage.

A self-administered questionnaire was used to gather data about current jobs and past blood exposures. Nonrespondents received up to two follow-up mailings. The questionnaire can be viewed at http://www.sra.com/paramedicquestionnaire/. Additional details of the study design have been given in a previous publication [Leiss et al., 2006]. This study was approved by the Human Investigation Committee of the University of Virginia.

Conceptual Model

Studies from the general worker safety literature show that management practices affect workers' safety-related behavior and risk of injury [Shannon et al., 1997; Torp et al., 2005]. The health care worker safety literature suggests that this general finding applies to needlestick injuries among hospital workers. Provision of safety-engineered medical devices is one management practice that has been associated with reduced risk of needlestick in hospital workers [Tan et al., 2001; Clarke et al., 2002a; Valls et al., 2007; Whitby et al., 2008], perhaps in conjunction with inclusion of employees' safety-related behavior in their job evaluations [Gershon et al., 1999], and among paramedics in two particular municipalities [O'Connor et al., 1996; Peate, 2001]. Among hospital workers, management support for employee safety has been associated with increased needle-related safe work practices [Vaughn et al., 2004], and supervisory correction of unsafe work behavior may be associated with reduced blood exposure (not limited to needlesticks) [Gershon et al., 2000]. Furthermore, in a previous analysis from the present study, supervisory behaviors that emphasized safe work practices and employer provision of relevant personal protective equipment were associated with reduced risk of getting blood on nonintact skin [Leiss, 2009].

Use of personal protective equipment would not be expected to affect the risk of needlestick. However, provision of personal protective equipment may be an indicator of management support for worker safety [DeJoy et al., 2000], which, as noted above, may influence the risk of needlestick. Thus, provision of personal protective equipment could be associated with risk of needlestick as an indicator of management practices that have a general effect on worker safety.

Workload has been associated with needlestick injury in health care workers [Clarke et al., 2002a]. Workload could affect the risk of needlestick in two ways. First, performing more procedures with needles would present more opportunities for needlesticks to occur. Second, a greater workload could represent elevated job demands [Vaughn et al., 2004], which could increase the risk of needlestick through fatigue and psychological mechanisms [Smith et al., 2006].

The above findings from previous studies suggest that management practices and workload may be related to the risk of needlestick among paramedics. Worker attitudes and beliefs, on the other hand, may be influenced by management practices [DeJoy et al., 2000], but they do not seem to affect safety-related behavior in the presence of the factors mentioned above [Vaughn et al., 2004]. Taken together, these findings from the literature suggest the causal model depicted in Figure 1 for the relation between management practices and needlesticks, which guided the present analysis. As represented in the model, provision of safety medical devices was expected to reduce the risk of

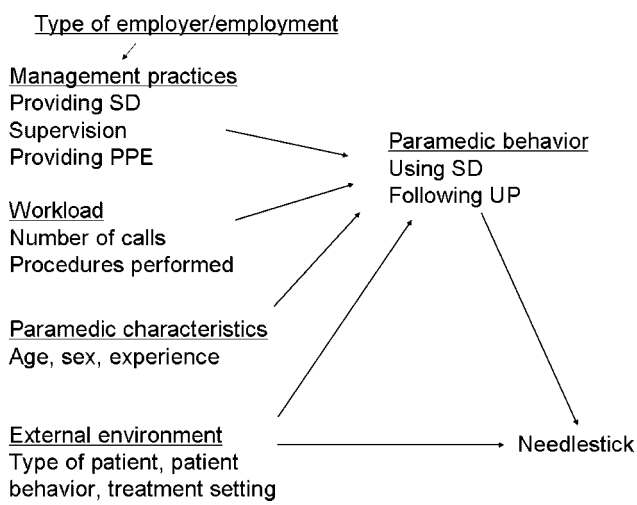

FIGURE 1. Directed acyclic graph showing the causal relations among management practices and needlesticks in paramedics. SD, safety devices; PPE, personal protective equipment; UP, Universal Precautions.

needlestick by altering the physical environment to reduce the potential for needlesticks to occur [Clarke et al., 2002a]. Supervisory emphasis on safe work practices was expected to reduce needlesticks by directly influencing paramedic behavior [Hofmann and Stetzer, 1996]. Provision of personal protective equipment was expected to reduce needlesticks by contributing to a positive safety climate [Gershon et al., 2000].

Data

Management practices

Paramedics were asked how often their squad or unit provided medical devices with safety features for each of five types of devices: shielded winged steel needles; retracting or shielded lancets; prefilled or cartridge syringes with sliding shields, hinged caps, or retracting needles; syringes (not prefilled or cartridge) with sliding shields, hinged caps, or retracting needles; and intravenous catheters with shielded or blunted stylets. Responses were indicated on a 5-point scale ranging from ''never'' to ''always.''

Similarly, paramedics were asked how often their squad or unit provided each of the following six types of personal protective equipment: leather gloves, safety goggles, face/surgical type masks, full-face shields, fluid-impermeable lab coats, and fluid-impermeable disposable coveralls. Response options were the same as for safety devices.

Paramedics were categorized as being always provided with 0–3 or 4–5 safety devices and 0–4 or 5–6 types of personal protective equipment. These categories were chosen to give the greatest precision (narrowest confidence intervals) for the risk ratio estimates. A detailed analysis of the safety device and personal protective equipment data was given previously [Mathews et al., 2008].

Paramedics were asked two questions about supervisory behavior with respect to safe work practices: ''If you did not follow Universal Precautions, would your supervisor speak to you about it?'' and ''Is following safety procedures part of your job evaluation?'' Response options were ''yes,'' ''no,'' and ''don't know.'' Because a supervisory behavior of which the paramedic is unaware is unlikely to influence his/her behavior, responses of ''don't know'' were included with ''no.'' Three supervisory behavior variables were examined in the analysis: one for each of the two supervisory behaviors, indicating that the paramedic was subject to that behavior without regard to the other, and one indicating that the paramedic was subject to both of the behaviors together versus none or only one of them.

Workload

Workload was measured by two variables, namely, the number of calls in the last 7 days in which the paramedic attended to a patient and the number of times the paramedic performed selected medical procedures in which a needlestick could potentially occur. The procedures counted were starting an IV/intraosseous line, administering medication via an IV/intraosseous line, performing a procedure using a lancet or scalpel, or performing a procedure using a medication vial/ampule. To examine interaction with management practices, this variable was defined as the total number of times the paramedic performed these procedures during the last four calls.

Needlesticks and paramedic characteristics

Cases were defined as paramedics who indicated being stuck by a needle or lancet after it had been used on a patient at least once during the previous 12 months. Experience was defined as number of years since paramedic certification. Age and sex were self-reported.

Classification with respect to job-specific variables

Twenty percent of the sample worked two jobs (including volunteer positions). Questions about the work environment (management practices and workload) were asked for each job the paramedic held at the time of the survey. The needlestick question, however, was not job-specific. This created the potential for misclassification of management practices and workload for cases who held two jobs. This issue was addressed by comparing the date of the most recent needlestick with the dates the paramedic started the two jobs. For most cases, the needlestick occurred after the start of one job only, or it occurred after the start of two different jobs but the work environment measures for the two jobs were identical. In the small number of cases where the two jobs had different work environment measures ($n = 3$ for safety devices, 9–12 for the supervisory behaviors, and 6 for personal protective equipment), the data from Job 1 were used. The analysis was repeated excluding these cases (data not shown), which caused little change in the results and no change in the conclusions. For noncases, the work environment data for Job 1 were used.

Statistical Analysis

Risk was defined as the percentage of paramedics who experienced a needlestick in the previous 12 months [Rothman, 2002]. SAS proc surveyfreq (version 9.1; SAS Institute, Cary, NC) was used to calculate proportions and confidence intervals incorporating sampling weights to adjust for the clustering and unequal probabilities of selection in the two-stage sampling design.

Potential confounders were identified using directed acyclic graphs (DAGs). In the DAG method, potential confounders are identified based on the causal relations among the variables rather than on the statistical relations; the considerations are conceptual rather than quantitative [Greenland et al., 1999]. The advantage of the DAG method is that it distinguishes between potential confounders and variables that are associated with both exposure and outcome but are not confounders. Failure to take the causal relations into account can lead to controlling for variables that are not confounders, which may introduce bias into the analysis [Hernan et al., 2002].

Applying this method to the model in Figure 1 shows that there are no known potential confounders for the association between the selected management practices and needlesticks (because there are no variables connected by arrows to both of these variables) [Glymour and Greenland, 2008]. However, the analysis allowed for the possibility of interaction (effect modification) between the management practices and workload or paramedic characteristics.

A sensitivity analysis was conducted to assess possible nonresponse bias. First, a mechanism by which nonresponse would produce biased risk ratio estimates was postulated [Greenland, 1998]. Then, the estimates were recalculated correcting for the hypothetical bias [Kleinbaum et al., 1982]. Specifically, it was assumed that nonresponse would be greater, relative to other paramedics, for cases whose management did not practice the supervisory behaviors. To correct for this hypothetical bias, the sampling weights of paramedics who fell into this category were doubled, and the risk estimates were recalculated using the corrected data. This correction is equivalent to assuming that the response rate for the selected group was half the response rate for other paramedics. Three sets of adjusted risk estimates were calculated corresponding to hypothetical nonresponse associated with each the three supervisory behavior variables.

Three questionnaire items asking the paramedic's opinions were used in the sensitivity analysis. These were ''Reporting blood exposures helps management protect paramedics from future exposures to patients' blood,'' ''I should be given more training in how to use safety devices,'' and ''I should be given more training in how to use PPE.'' Response options were 1, labeled *disagree*, to 5, labeled *agree*. A summary measure was constructed that counted the number of times (up to 3) the paramedic indicated ''4'' or ''5'' for the first item and ''1'' or ''2'' for the other two items.

RESULTS

Ten states were selected in the first stage. One state (Illinois) refused to participate. Based on mail that was returned undelivered, 5.5% of the sample could not be contacted because of incorrect addresses. A total of 3,378 questionnaires were received from the 6,142 paramedics presumed to have been contacted. Of these respondents, 2,664 met the eligibility criteria included in the questionnaire. Assuming that the proportion of ineligibles among nonrespondents was the same as among respondents, the response rate was 55% (2,664/4,844).

A fourth of paramedics were always provided with more than three types of safety devices and a fourth were always provided with more than four types of personal protective equipment. Three-fourths of paramedics were subject to at least one of the supervisory behaviors emphasizing safe work practices (Table I).

Overall, 118 (6.7%) paramedics reported having a needlestick in the previous year. Compared to their counterparts, the risk was greater for paramedics who made more calls and for paramedics who performed more of the selected procedures. Similarly, the risk was greater for paramedics aged <30 years and for females (Table II). The excess risk for females appeared to be limited to the younger age group, but low precision (wide confidence intervals) makes this quite uncertain (data not shown).

Provision of safety devices and the supervisory behaviors emphasizing safe work practices were associated with

TABLE I. Distribution of Management Practices and Job Conditions in U.S. Paramedics, 2002–2003 (n = 2,664)

	%
Management practice	
Always provides >3 types of safety devices[a]	24
Following safety procedures is part of job evaluation[b]	74
Supervisor would speak to paramedic if did not follow UP[b]	72
Following safety procedures is part of job evaluation and supervisor would speak to paramedic if did not follow UP	61
Always provides >4 types of personal protective equipment[c]	23
Job conditions	
Made >14 calls in past 7 days	44
Performed >2 selected procedures on last 4 calls[d]	52
Paramedic characteristics	
Age <30 years	20
Female	18
Experience <5 years	25

UP, Universal Precautions.

[a]Safety devices provided could be shielded winged steel needle; retracting or shielded lancet; prefilled or cartridge syringe with sliding shield, hinged cap, or retracting needle; syringe (not prefilled or cartridge) with sliding shield, hinged cap, or retracting needle; and IV catheter with shielded or blunted stylet.

[b]These two categories are not mutually exclusive.

[c]Equipment provided could be safety goggles, face/surgical type mask, full-face shield, leather gloves, fluid-impermeable lab coat, and fluid impermeable disposable coveralls.

[d]Procedures performed could be starting an IV/intraosseous line, administering medication via an IV/intraosseous line, performing a procedure using a lancet or scalpel, or performing a procedure using a medication vial/ampule.

TABLE II. Twelve-Month Risk of Needlestick in U.S. Paramedics, by Selected Job Conditions and Paramedic Characteristics, 2002–2003 (n = 2,664)

Characteristic	Risk (%)	95% CI
Total	6.7	5.4–7.9
Job conditions		
Made <15 calls in past 7 days	4.6	2.3–6.9
Made 15+ calls in past 7 days	9.9	5.0–15
Performed <3 selected procedures on last 4 calls[a]	4.3	1.8–6.9
Performed 3+ selected procedures on last 4 calls[a]	8.8	5.4–12
Paramedic characteristics		
Age <30 years	9.1	5.7–13
Age 30+ years	6.0	4.5–7.6
Female	9.0	6.8–12
Male	6.1	4.8–7.4
Experience <5 years	6.7	3.4–10
Experience 5+ years	6.8	4.3–9.3

CI, confidence interval.

[a]Procedures counted were starting an IV/intraosseous line, administering medication via an IV/intraosseous line, performing a procedure using a lancet or scalpel, or performing a procedure using a medication vial/ampule.

reduced risk; risk ratios ranged from 2.5 to 3.2 (Table III). The effect of the two supervisory behaviors together was greater than the effect of either of them separately. The effects of provision of safety devices and the supervisory behaviors were greater for paramedics aged <30 years than for older paramedics, but the precision of these estimates was low (i.e., wide confidence intervals). Low precision prevented meaningful interpretation of interaction (effect modification) between the management practices and years of experience and the workload variables.

The sensitivity analysis corrected for hypothetical greater nonresponse among cases whose management did not follow the supervisory behaviors. Most of the corrected risks (Table IV) are greater than the uncorrected risks (Table III). Furthermore, the corrected risk ratios for provision of safety devices and the supervisory variables are greater than the comparable uncorrected risk ratios. Regarding the opinion questions, for each of the three supervisory behavior variables, 31% of paramedics who were subject to the behavior had a value of 3 on the summary measure, compared to 19% of paramedics who were not subject to the behavior.

DISCUSSION

The influence of management practices on worker safety has been recognized in the general safety literature [Shannon et al., 1997; Torp et al., 2005] as well as the health care worker safety literature [Mark et al., 2007]. However, the effect of management practices on needlesticks in a general population of paramedics has not been reported previously. This study found that among U.S. paramedics, two management practices were associated with reduced risk of needlestick. One of the management practices was provision of safety-engineered medical devices that are designed to remove unprotected needles from the work environment after they have been used on a patient (or that replace needles with needleless devices). In a previous analysis from this study, we found that paramedics who reported always being provided with safety devices also reported greater use of the devices [Mathews et al., 2008]. The present analysis suggests that providing safety devices to paramedics does in fact reduce their risk of needlestick. However, provision of safety devices alone will not prevent all needlesticks—20% of the needlesticks in this study occurred *with* safety devices [Leiss et al., 2009]. Studies of hospital health care workers have shown that workers need training in how to use safety devices in order to receive the full protective benefit of those devices [Rivers et al., 2003; Adams and Elliott, 2006]. Taken together, these results suggest that increased provision of safety devices combined with adequate training in their use could reduce blood exposure from needlesticks in U.S. paramedics.

At the time of this survey, only one-fourth to three-fourths of paramedics were always provided with safety devices, depending on the type of device [Mathews et al., 2008]. In contrast, the Bloodborne Pathogens Standard [Occupational Safety and Health Administration, 2007b], as intended by the Needlestick Safety and Prevention Act [Needlestick Safety and Prevention Act, 2000], requires employers to provide all relevant safety devices at all times. Future research should address two major questions: (1) to what extent are paramedics now being provided with safety devices; if provision is less than optimal, what interventions are needed to increase it, and in particular, why has the revised Bloodborne Pathogens Standard not led to the intended levels of provision; and (2) what further interventions (e.g., training) are needed to enable paramedics to receive the full protection potentially offered by the safety devices that are being provided?

The second management practice that was associated with reduced risk of needlestick was supervisory behaviors that emphasize safe work practices [Hofmann et al., 1995]. Paramedics who worked in a managerial environment in which failure to follow Universal Precautions elicited an active response from supervisors had reduced risk of needlestick. Similarly, paramedics who worked in a managerial environment in which following safety procedures was an explicit criterion for performance evaluation had reduced risk of needlestick. Moreover, the protective effect of working in an environment that included both of the supervisory behaviors was greater than the protective effect of being always provided with safety devices (Table III). It should be noted that these supervisory behaviors were also associated with reduced blood exposure from another route, nonintact skin [Leiss, 2009].

TABLE III. Twelve-Month Risk (%) of Needlestick in U.S. Paramedics, by Selected Management Practices and Paramedic Age and Sex, 2002–2003 (n = 2,664)

	Practice followed by management			Practice not followed by management			Risk ratio	
Management practice and paramedic age and sex	**No. of cases**	**Risk**	**95% CI**	**No. of cases**	**Risk**	**95% CI**	**RR**	**95% CI**
Provides >3 types of safety devices[a]	24	2.8	1.3–4.2	94	7.9	6.2–9.7	2.9	1.2–4.6
<30 y	6	2.8	0–6.0	26	11	6.5–16	4.0	0–8.8
30+ y	18	2.8	1.1–4.4	67	7.1	4.9–9.3	2.6	0.8–4.3
Male	18	2.2	0.8–3.6	67	7.3	5.9–8.7	3.3	1.1–5.6
Female	6	4.8	0.4–9.1	27	11	6.2–15	2.2	0–4.4
Following safety procedures is part of job evaluation[b]	69	4.4	3.4–5.4	44	12	9.5–14	2.6	1.9–3.4
<30 y	14	3.4	1.2–5.5	15	20	17–23	5.8	2.0–9.9
30+ y	55	4.7	3.6–5.9	28	9.2	5.6–13	1.9	1.0–2.8
Male	48	4.0	2.3–5.7	34	11	6.6–15	2.7	1.1–4.3
Female	21	6.5	4.3–8.7	10	15	4.7–26	2.4	0.5–4.2
Supervisor would speak to paramedic if did not follow UP[b]	72	4.7	3.9–5.6	44	12	9.2–15	2.5	1.8–3.3
<30 y	12	3.4	0–6.9	17	20	14–27	5.9	0–12
30+ y	58	5.0	3.7–6.3	27	9.8	7.4–12	2.0	1.3–2.7
Male	53	4.9	3.8–5.9	32	9.7	6.9–13	2.0	1.3–2.7
Female	19	4.3	2.7–5.9	12	23	15–31	5.4	2.7–8.1
Following safety procedures is part of job evaluation and supervisor would speak to paramedic if did not follow UP[c]	54	3.7	2.9–4.4	62	12	9.9–13	3.2	2.3–4.0
<30 y	8	1.6	0.1–3.1	22	18	15–20	11	0.8–21
30+ y	46	4.1	3.2–5.1	39	9.7	7.4–12	2.3	1.6–3.1
Male	38	3.6	2.4–4.7	47	10	9.0–12	2.9	1.9–3.9
Female	16	4.1	2.6–5.7	15	17	11–24	4.1	1.9–6.4
Provides >4 types of PPE[d]	30	4.8	3.5–6.1	88	7.2	5.6–8.8	1.5	1.0–2.0

CI, confidence interval; PPE, personal protective equipment; RR, risk ratio; UP, Universal Precautions; y, years.
Total number of subjects varies across categories because of item nonresponse.
[a]Safety devices provided could be shielded winged steel needle; retracting or shielded lancet; prefilled or cartridge syringe with sliding shield, hinged cap, or retracting needle; syringe (not prefilled or cartridge) with sliding shield, hinged cap, or retracting needle; and IV catheter with shielded or blunted stylet.
[b]These two categories are not mutually exclusive.
[c]Compared to none or only one of the management practices.
[d]Equipment provided could be safety goggles, face/surgical type mask, full-face shield, leather gloves, fluid-impermeable lab coat, and fluid impermeable disposable coveralls.

The two supervisory behaviors examined in this study are likely elements of a complex structure of organizational factors that affect paramedics' risk of needlestick [Tan et al., 2001; Vaughn et al., 2004; Mark et al., 2007]. The strong associations found in this study suggest that interventions aimed at management behaviors could substantially reduce paramedics' risk of needlestick. Future research should draw on the general occupational safety literature [Hofmann and Morgeson, 1999] as well as studies focusing on health care workers [Vredenburgh, 2002] to develop such interventions.

The increased risk for paramedics who made more calls and for those who performed more procedures could be the result of elevated job demands, or it could simply reflect their greater opportunity for exposure. Future research should examine the role of workload in increasing the risk of needlestick among paramedics. The excess risk among younger and female paramedics may indicate a need for interventions designed to reduce needlesticks in these groups in particular. Alternatively, it could be the result of more complete reporting of needlesticks on the survey by these groups. Female paramedics indicated they would be more likely to report needlesticks to their employer [Boal et al., 2008], but whether this is reflected in reporting on the survey is not known. Further research is needed to resolve these questions.

Potential Bias

The 55% response rate raises the possibility of nonresponse bias. A low response rate causes bias when the mechanism that selects respondents from nonrespondents is related to the study factors [Groves et al., 2006]. For the present analysis, nonresponse would cause biased risk ratio estimates if one group of cases, either those who were subject

TABLE IV. Twelve-Month Risk (%) of Needlestick in US Paramedics by Selected Management Practices, Adjusted for (Hypothetical) Nonresponse Bias from Hypothetical Nonresponse Associated With the Management Practices, 2002–2003 (n = 2,664)

Management practice[a]	Adjusted risks[b] assuming that nonresponse was greater for cases for whom following safety procedures was not part of job evaluation			Adjusted risks[b] assuming that nonresponse was greater for cases whose supervisor would not speak to paramedic if he/she did not follow UP			Adjusted risks[b] assuming that nonresponse was greater for cases for whom following safety procedures was not part of job evaluation and supervisor would not speak to paramedic if he/she did not follow UP		
	Practice followed	Practice not followed	Risk ratio	Practice followed	Practice not followed	Risk ratio	Practice followed	Practice not followed	Risk ratio
Provides >3 types of safety devices	3.4	11	3.3	3.4	12	3.4	3.6	13	3.5
Following safety procedures is part of job evaluation[a]	4.4	21	4.7	5.8	19	3.2	5.8	21	3.6
Supervisor would speak to paramedic if he/she did not follow UP[a]	5.8	19	3.2	4.7	22	4.5	6.3	22	3.4
Following safety procedures is part of job evaluation and supervisor would speak to paramedic if he/she did not follow UP[c]	3.7	18	4.9	3.7	18	5.1	3.7	21	5.7
Provides >4 types of PPE	6.8	10	1.5	5.9	11	1.8	7.1	12	1.6

UP, Universal Precautions; PPE, personal protective equipment.
[a]These two categories are not mutually exclusive.
[b]The adjusted risks were based on the assumption that these cases were 50% underrepresented relative to other paramedics.
[c]Compared to none or only one of the management practices.

to the management practice or those who were not, had a lower response rate than other paramedics. The possibility of nonresponse bias through this mechanism was suggested by the frequent statement of paramedics, during informal contacts with the research team, that they would not want their employer to know about their needlestick because they would suffer negative repercussions.

An indication of which group of cases would be less likely to respond because of the above concern is given by noting that, in studies of organizational environment and worker safety, the supervisory behaviors examined in this study are similar to factors included as elements of a positive safety climate; a positive safety climate is marked by encouragement from management to report blood exposures without suffering negative consequences [Mark et al., 2007]. Consistent with this literature, a greater percentage of paramedics who were subject to the supervisory behaviors indicated they would report needlesticks and other blood exposures to their employers compared to paramedics who were not subject to the supervisory behaviors (~83% vs. 65% for needlesticks and 56% vs. 43% for total blood exposures) [Boal et al., 2008]. Similarly, among the 27 paramedics who experienced a needlestick but did not report it to their employer, four did not report it because they did not want to be reprimanded. Three of these paramedics were not subject to either of the supervisory behaviors (data not shown). In addition, the three opinion questions are similar to items typically included in safety climate scales [Gershon et al., 2000; Flin et al., 2006]. Paramedics who were subject to the supervisory behaviors were more likely to respond to these questions in a manner compatible with a positive safety climate.

The foregoing data suggest that cases who were not subject to the supervisory behaviors would be less likely to participate in the survey than other paramedics. The sensitivity analysis examined possible nonresponse bias under this assumption. Although the degree of relative nonresponse assumed in the sensitivity analysis (i.e., 50%) was arbitrary, the *direction* of the bias would be the same for greater and lesser degrees of relative nonresponse. Thus, the results show that if nonresponse bias was, in fact, generated by the above scenario, it may have caused underestimation of the true risks and risk ratios, but it did not cause overestimation.

As described in the Materials and Methods Section, there may be some misclassification of management practices among paramedics who changed jobs or held two jobs during the previous year. The likely nondifferential nature of this misclassification along with the small number of ambiguous cases and the slight impact on the results of excluding those cases suggest that any bias from this source would be minor.

The needlestick data refer to injuries that occurred over the previous year, whereas the management practice data refer to the practices that were in effect at the time of the survey. It is possible that management practices changed during the year in

response to needlestick injuries, which would violate the causality assumption implicit in Figure 1. However, if needlestick injuries had caused management to begin providing safety devices or to implement the supervisory behaviors emphasizing safe work practices, the data would show *increased* risk associated with these management practices, the opposite of what was found.

Considering the above potential sources of bias together, the strongest conclusion is that the effects of the management practices found in this study may be underestimates to some degree, but they are unlikely to be overestimates. Thus, they provide a reasonable basis for developing policy and intervention programs.

CONCLUSIONS

Considered in the context of research on organizational influences on worker safety, the strong protective effects of the supervisory behaviors (Table III) suggest that interventions aimed at management practices that promote worker safety could substantially reduce the risk of needlestick among paramedics [DeJoy et al., 2004; Vredenburgh, 2002]. Considered in the context of research on safety devices and needlesticks among health care workers, the strong protective effect of providing safety devices (Table III) suggests that greater provision of safety devices to paramedics could substantially reduce their risk of needlestick [O'Connor et al., 1996; Peate, 2001]. Provision of the devices should be accompanied by adequate training in order for paramedics to receive the full protective benefit of the devices [Rivers et al., 2003; Adams and Elliott, 2006]. Given the high level of risk found in this study—7% per year—follow-up surveillance seems warranted.

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