studies specifically addressed mortality in women. Kark et al. (7) reported a positive association between homocysteine level and mortality among men and women in Israel, but when women were analyzed separately, the adjusted association was no longer statistically significant. Ridker et al. (8) reported that homocysteine level was a risk factor for cardiovascular events in postmenopausal women, but did not provide mortality data. In our study, the effects of homocysteine on mortality did not vary by sex.

Using mortality as an outcome may have introduced a bias towards identifying factors associated with acute and severe (i.e., fatal) consequences of atherosclerosis, such as thrombosis.

In conclusion, our findings are consistent with the small number of studies that suggest an association between serum homocysteine levels and all-cause mortality, regardless of baseline cardiovascular disease.

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Sharps-Related Injuries in Health Care Workers: A Case-Crossover Study

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Injuries caused by sharp medical devices are common among health care workers in the United States. The best available data suggest that between 400,000 and 800,000 such injuries occur in hospitals each year (1–3).

These injuries are a source of concern because of their potential to transmit various infectious agents, including hepatitis B virus (4), hepatitis C virus (5), and human immunodeficiency virus (HIV) (6,7). The evaluation and treatment of these injuries and subsequent illnesses impose a heavy societal burden in terms of economic cost (8), worker anxiety and distress (9,10), and future morbidity (1,3–5,11–13).

The current hospital environment presents employees with various challenges, including worker fatigue, rushing, and distraction (14–16). We postulated that such brief, transient factors might increase the risk of sharps-related injuries in health care workers. We performed a case-crossover study—a design in which each "case" serves as his or her own control—to identify and quantify transient factors that might increase the risk of such injuries (17,18). This design has been used to investigate risk factors for injuries and accidents in other settings (19–23).

METHODS

Subjects

Subjects were health care workers employed at the University of Maryland Medical Center in Baltimore, Maryland, or at the Beth Israel Deaconess Medical Center in Boston, Massachusetts. Employees who reported a sharps-related injury sustained while handling a contaminated medical device were considered eligible for the study, and were invited to participate by occupational health services staff at the time of postexposure risk assessment. Participating subjects were interviewed by telephone using a standardized questionnaire. Employees were considered ineligible for participation if they had been injured by a clean or unused medical device, or if they had suffered a skin or mucus membrane splash with blood or body fluids without skin puncture or laceration. All subjects provided written informed consent, and the study was approved by the institutional review boards of the University of Maryland Medical Center and Beth Israel Deaconess Medical Center.

Study Design

The case-crossover study design is characterized by self-matching, in which the case and control data are obtained from the same subject (17,23). The use of such an approach permits assessment of the relation between brief, transient exposures (such as fatigue or rushing) and an acute event (in this case, the occurrence of a sharps-related injury). This design adjusts for many of the differences between cases and controls that might confound the results of a more traditional case-control study.

Between February 2000 and October 2001, 139 subjects who reported sharps-related injuries to employee health services were recruited at the two medical centers. The median time from assessment in employee health services to interview was 3 days, and 90% (n = 123) of subjects were interviewed within a week of injury.

Exposure Assessment

In all subjects, we assessed rushing, distraction, anger, fatigue, performance of a task in an emergency situation, and teaching. In subjects who were not scrubbed in an operating room or procedure suite at the time of injury, we also assessed repeated attempts to perform procedures, staffing shortages, and the presence of an uncooperative patient. Subjects who were scrubbed in an operating room or procedure suite at the time of injury were asked about the presence of a bloody operative field, excess noise in the operating room or procedure suite, and the performance of highly complex procedures. Trainees were asked whether or not they were being taught at the time of the injury. Subjects were asked whether these factors had been present on the day of the injury, and if so, whether they had been present at the time of the injury.

Subjects were asked to estimate their average time at risk of sharps-related injuries. Those who were not scrubbed at the time of injury were considered to have a noncontinuous risk of sharps-related injury, and time at risk was estimated as the product of the number of procedures performed in the last month and average procedure duration. Among those who were scrubbed at the time of injury, risk of injury while scrubbed was considered to be continuous, and time at risk was estimated as the number of hours spent scrubbed in an operating room or procedure suite within the past week. The usual frequencies of exposures were estimated as the proportion of time (while at risk of sharps-related injuries) that subjects experienced a given exposure. Example questions are provided in the Appendix.

Reliability of Measurements

From December 2000 to October 2001, we assessed the reliability (reproducibility) of subjects' estimates of time at risk, exposure frequency, and presence of exposures at the time of injury in a subset of 40 study participants. At the termination of the original interview, subjects were asked whether they would be willing to participate in a second interview, in exchange for additional reimbursement. They were re-interviewed between 2 and 5 days after their initial interview, using an abbreviated version of the original questionnaire.

Statistical Analysis

Usual frequency estimates were used to estimate the subject-specific person-time exposed and unexposed to each transient risk factor during the past week (among those at continuous risk) or past month (among those at noncontinuous risk). Data were analyzed using standard methods for case-crossover data (24). We estimated the incidence rate ratio as a measure of relative risk using the

Mantel-Haenszel estimators for person-time data (25); its variance was computed using standard methods (26).

We calculated intraclass correlation coefficients for subjects' estimates of time at risk and exposure frequency using a random-effects model for repeated measurements by a single observer (27). Reproducibility of subjects' assessment of the risk status of the source patient, and of exposure at the time of injury was assessed using the κ statistic (28) and classified (29). We tested for an interaction between exposure and whether (or not) the source patient had a known infection with HIV or hepatitis virus (30).

All statistical analyses were performed using SAS, version 8.01 (SAS Institute, Cary, North Carolina), except for reliability analyses, which were performed using SPSS, version 10.0 (SPSS Inc, Chicago, Illinois).

RESULTS

The majority of subjects were women, and most injuries were incurred by nurses or trainees, including medical students, nursing students, and residents (Table 1). Most injuries occurred with hollow-bore devices. Definite or suspected exposure to HIV, hepatitis B virus, or hepatitis C virus was reported by approximately half of the subjects. A minority of subjects incurred their injuries in a continuous-risk environment, such as an operating room or procedure suite.

Table 1. Characteristics of the Sample (n = 139)

Characteristic	Number (%), Mean ± SD, or Median (Range)*
Age (years)	34 ± 10
Days until interview	3 (0–15)
Female sex	100 (72)
Job description	
Nurse	63 (45)
Medical or surgical resident	36 (26)
Surgical or laboratory technician	9 (7)
Staff physician or surgeon	7 (5)
Student	9 (7)
Other	15 (11)
Device causing injury	
Hollow-bore needle	91 (66)
Suture needle	24 (17)
Scalpel, blade, or scissors	10 (7)
Stylette or trocar	6 (4)
Other	8 (5)
Continuous risk†	32 (23)
Known exposure to HIV or hepatitis C virus	24 (17)
Suspected exposure to HIV or hepatitis C virus	38 (27)

* Percentages may not add up to 100 due to rounding.
† Defined as scrubbed in an operating room or procedure suite at the time of injury.
HIV = human immunodeficiency virus.

Risk Factors for Sharps-Related Injuries

There was substantial variability in the prevalence of exposures of interest during the hazard period (i.e., the period during which the injury occurred), and in the average frequency of exposure while performing similar tasks in the control time period (Figure). An increased risk of sharps-related injury was associated with rushing, anger, distraction, and multiple passes. A trend toward increased risk was seen when subjects were fatigued, working with an uncooperative patient, or working as part of a team that was short staffed, and among surgeons working in a noisy operating room environment (Table 2). Among trainees scrubbed in an operating room or procedure suite, the risk of injury appeared to decrease in association with being taught, and a trend toward decreased risk of injury was seen with emergency procedures. No change in the risk of sharps-related injuries was found in association with teaching, performing highly complex operative procedures, or working in a bloody operative field.

Stratified analyses were performed to evaluate whether exposure effects were modified by the source patient's infection status. The risk of injury with multiple passes was higher when source patients were known or suspected to be infected with HIV or hepatitis C virus than when such infection was not suspected (relative risk = 6.1 [95% confidence interval {CI}: 2.6 to 14.4] vs. 1.3 [95% CI: 0.4 to 3.6], P for interaction = 0.02). Infection status did not affect the risk associated with other exposures.

Reproducibility of Measures

The reproducibility of estimated time at risk was excellent (Table 3). Subjects' assessments of whether the exposure was "high risk" (defined as exposure to a source patient known or suspected to be infected with HIV or hepatitis C virus) was also highly reproducible. Intraclass correlation coefficients for the usual frequency of exposures while at risk of sharps injury were good or excellent for all exposures. Reproducibility of the presence of exposures at the time of injury ranged from substantial (in the case of anger), to almost perfect (in the case of rushing).

DISCUSSION

We used a case-crossover study design to identify and evaluate the effects of common workplace factors on the risk of sharps-related injuries in health care workers. Among subjects participating in the study, distraction, anger, and rushing were associated with the largest increase in the risk of sharps-related injuries. Free text recorded by interviewers suggests that the source of distrac-

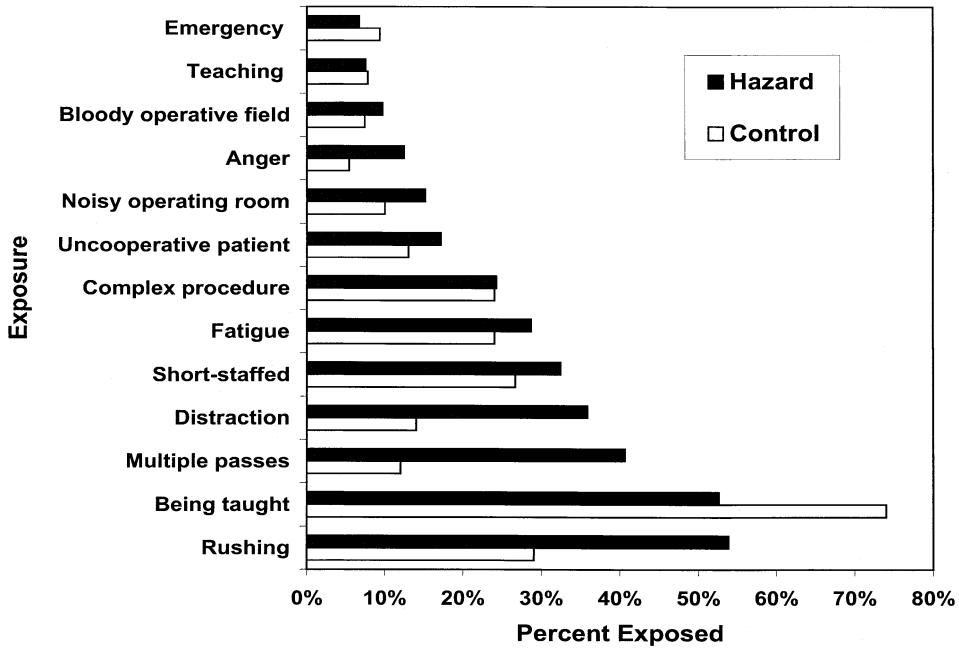

Figure. Frequency of exposure during hazard and control periods. Black bars represent the proportion of study subjects reporting an exposure during the hazard period (i.e., at the time of injury). White bars represent the average frequency of exposure during the control period. Incidence rate ratios for exposures of interest were calculated using stratified analytic methods, so that ratios cannot be calculated directly from the Figure.

tion was frequently an interaction with a coworker while performing a procedure. Distractions were often trivial in nature, an observation supported by the finding that emergency situations did not increase the risk of sharps-related injuries. Anger was most often associated with conflict with another employee or with a patient. This

Table 2. Estimates of the Effect of Workplace and Individual Level Exposures on the Risk of Sharps-Related Injuries

Exposure	Number (%) Exposed at the Time of Injury	Incidence Rate Ratio (95% Confidence Interval)	*P* Value
All subjects (n = 139)			
Rushing	67 (48)	3.3 (2.5–5.0)	<0.001
Fatigued	39 (28)	1.5 (0.9–2.3)	0.11
Distracted	49 (35)	8.9 (5.1–16)	<0.001
Angry	17 (12)	5.5 (2.7–11.1)	<0.001
Emergency situation or procedure	9 (6)	0.5 (0.15–1.5)	0.19
Teaching	11 (8)	0.9 (0.3–2.3)	0.77
Noncontinuous risk (n = 106)*			
Uncooperative patient	19 (18)	1.8 (1.0–3.3)	0.07
Short-staffed†	24 (32)	1.6 (0.9–2.8)	0.11
Multiple passes‡	24 (41)	3.1 (1.8–5.5)	<0.001
Continuous risk (n = 33)*			
Being taught§	10 (53)	0.1 (0.02–0.7)	0.02
Bloody operative field	4 (12)	1.5 (0.4–5.0)	0.53
Highly complex procedure	9 (26)	0.9 (0.3–2.4)	0.87
Noisy work environment	5 (15)	2.1 (0.7–6.6)	0.21

* Continuous risk was defined as scrubbed in an operating room or procedure suite at the time of injury. All other subjects were considered to be at noncontinuous risk of shaprs-related injury.

† Question introduced in later versions of questionnaire (n = 75 subjects).

‡ Defined as more than one attempt to perform the procedure. Question posed only to subjects (n = 59) performing phlebotomy, arterial blood gas measurement, intravenous catheter insertion, central venous catheter placement, arthrocentesis, and lumbar puncture at the time of injury.

§ Question posed only to trainees (n = 19).

Table 3. Reproducibility of Responses to Needlestick Questionnaire among 40 Subjects Re-interviewed after 2 to 5 Days

	Intraclass Correlation Coefficient (95% Confidence Interval)	κ (95% Confidence Interval)
Time at risk	0.96 (0.93–0.98)	—
High-risk exposure*	—	0.88 (0.80–0.96)
Exposures	Usual frequency	Exposed when injured
Rushing	0.88 (0.79–0.93)	0.88 (0.80–0.96)
Fatigued	0.79 (0.63–0.88)	0.84 (0.75–0.94)
Distracted	0.69 (0.49–0.82)	0.89 (0.82–0.97)
Angry	0.98 (0.97–0.99)	0.75 (0.62–0.89)
Emergency situation or procedure	0.99 (0.97–0.99)	0.89 (0.79–1.0)
Teaching	0.97 (0.93–0.98)	0.88 (0.75–1.0)

* Defined as exposure to a source patient known or suspected to be infected with human immunodeficiency virus or hepatitis C virus.

suggests that worker education on the importance of not disturbing colleagues working with sharp devices, and on the importance of "cooling off" after an interpersonal conflict before attempting a procedure, could help to prevent future sharps-related injuries.

The association between rushing and injury is more problematic, as rushing may be difficult to avoid in the current health care environment. However, if rushing is associated with sharps-related injuries, critical evaluation of the current pace of work and staffing ratios in health care institutions could lead to strategies that reduce such injuries.

Multiple attempts to complete a procedure were also associated with an increased risk of injury. Repeated attempts at procedure completion have also been associated with patient injury (31,32). In contrast with previous studies, we failed to find a significant increase in injury risk among surgeons exposed to bloody operative fields (33,34), although our study may have lacked statistical power to demonstrate such a relation, given the relatively small number of surgeons.

As with any study that involves retrospective data collection from human subjects, our results are potentially vulnerable to recall bias; however, this limitation would apply equally to case-control or cohort studies of sharps-related injuries. Relative to these designs, the case-crossover study design may have the advantage of internal consistency in exposure assessment, in that the same person ascertains the presence of the exposure in both the hazard and control periods. Nonetheless, underreporting of sharps-related injuries could be a source of selection bias in our study, particularly if certain factors associated with injuries made subjects more likely to report them (17).

Some exposures that we evaluated, such as being short staffed, might be less susceptible to biased reporting, as they would be more "objective" than such abstract exposures as anger or distraction. Although we cannot compare subjects' assessments of such exposures with a gold standard, these assessments were extremely reliable when obtained again at a later date. This reliability suggests that subject estimates were based on clear perceptions of time at risk, exposure frequency, and the presence of exposure at injury.

Our findings that distraction, anger, and rushing increase the risk of sharps-related injuries are robust and have substantial face validity. Interventions to minimize these factors should be explored by those who wish to prevent sharps-related injuries in the health care workplace.

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APPENDIX

Sample Questions

A. Noncontinuous risk, exposure of interest: fatigue

1. At any time on the day of your injury, did you feel fatigued or tired?

Yes No

If yes, then ask:

2. Did you feel fatigued or tired at the time of your injury?

Yes No

Always ask:

3. You said you performed (task) (#) times in the last month. How many times in the last month did you perform (task) while fatigued or tired, up to and including your injury?

__ Times

B. Continuous risk, exposure of interest: bloody operative field

1. At any time on the day of your injury, was the operative field obscured by blood?

Yes No

If yes, then ask:

2. Was the operative field obscured by blood at the time of injury?

Yes No Not applicable

Always ask:

3. What percentage of the time, while you scrubbed in the operating room or procedure suite in the past week, was the operative field obscured by blood?

__%

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