Occupational Exposures to Body Fluids among Medical Students

A Seven-Year Longitudinal Study

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Background: Medical students may be at high risk for occupational exposures to blood.

Objective: To measure the frequency of medical students' exposure to infectious body substances, to identify factors that affect the probability of such exposure, and to suggest targets for the prevention of such exposure.

Design: Review of all exposures reported by medical students at the University of California, San Francisco, School of Medicine.

Setting: Teaching hospitals affiliated with the University of California, San Francisco.

Participants: Third- and fourth-year medical students from the classes of 1990 through 1996 at the University of California, San Francisco, School of Medicine.

Interventions: A needlestick hotline service was instituted at teaching hospitals affiliated with the University of California, San Francisco, and a required course was created to train students in universal precautions and clinical skills before the beginning of the third-year clerkship.

Measurements: Reports of exposures made to the needlestick hotline service, including type of exposure, training site, clerkship, and time of year.

Results: 119 of 1022 medical students sustained 129 exposures. Of these exposures, 82% occurred on four services: obstetrics–gynecology, surgery, medicine, and emergency medicine. The probability of exposure was not related to graduation year, clerkship location, previous clerkship experience, or training site. Surveys of two graduating classes at the beginning and end of the study showed that the percentage of exposures reported increased from 45% to 65% over the 7-year study period. Thus, the reported injury rates represent minimum estimates of actual occurrences. Human immunodeficiency virus infection and hepatitis were not reported, although follow-up was limited.

Conclusions: Instruction in universal precautions and clinical procedures is not sufficient to prevent exposures to blood during medical training. Medical schools must assume greater responsibility for ensuring that students are proficient in the safe conduct of clinical procedures and must develop systems that protect students so that they can report and learn from their mistakes.

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Medical students may be vulnerable to accidental exposures to blood because they lack experience and skill, even though they are eager to learn new procedures (1–7). The risk for exposure to and infection by bloodborne pathogens among medical students is not known, and published reports probably underestimate the actual risk because many exposures are not reported. Health care workers, especially physicians in training (2, 4, 6), often do not report exposures because of fear of losing insurance and employment, disbelief in the efficacy of prophylaxis, or a tendency to deny personal risk.

Early in the course of the AIDS epidemic, the University of California, San Francisco, recognized the potential risk for exposure among medical students, and it implemented curricular changes to encourage universal precautions and the safer use of needles during bedside procedures. It also created a comprehensive postexposure care system, including needlestick hotlines, to facilitate reporting of exposures at the teaching hospitals affiliated with the University of California, San Francisco, for all health care workers, including students. However, surveys of graduating students showed that many accidental exposures occurred despite the training given.

Our study was done to 1) identify factors associated with occupational exposure that might be modified to protect medical students from unnecessary risk and 2) describe the epidemiology of occupational exposures sustained by medical students at the University of California, San Francisco, over a 7-year period.

Methods

We hypothesized that the following variables might be associated with the probability of occupational exposure to blood: type of clerkship, previous completion of a clerkship in an area suspected of conferring a high risk for occupational exposure

See editorial comment on pp 66-67.

(obstetrics [2], surgery [3], or medicine [4–6]), and year of graduation (7). All occupational exposures reported by medical students who graduated from the University of California, San Francisco, School of Medicine between 1990 and 1996 were retrospectively reviewed. Eligible exposures were only those reported between June 1989 and May 1996. Exposures occurred through needle punctures, lacerations, and other injuries caused by sharp objects; mucosal splashes; and contact of nonintact skin with blood or bloody body fluids.

Data Collection

Occupational exposures were initially reported to needlestick hotlines, which are managed by employee health services, at the hospitals affiliated with the University of California, San Francisco. In 1989, San Francisco General Hospital instituted the first hotline, through which housestaff, students, staff, and faculty could report occupational exposures. In June 1990, similar programs were implemented at all of the other hospitals in San Francisco that are affiliated with the University of California, San Francisco: Moffitt-Long Hospital, the Veterans Affairs Medical Center, and Mt. Zion Hospital. These hotlines were endorsed by the Chancellor's AIDS Coordinating Committee at the University of California, San Francisco, and were designed to be anonymous, available 24 hours a day, and staffed by experts in exposure management.

Students were encouraged to report injuries to the hotline service closest to them. During their orientation to clerkships, students received pocket-sized laminated cards printed with the telephone numbers of the hotlines at the various hospitals. These cards were also given to all new housestaff and were prominently displayed in emergency departments, nursing stations, and resident lounges at all hospitals. Students who reported an exposure to the hotline received baseline and follow-up care at the employee health services on the campus where the exposure occurred. Students could report occupational exposures to the Student Health Service before 1991, but after this date, the hotlines were available at all sites and all exposed students were managed by employee health services. Thus, this study used data derived from the employee health services hotlines.

The clerkship schedules for each eligible medical student were provided by the Office of Student and Curricular Affairs to a statistician who had no access to reported exposure data. This statistician assigned each student a study identification number from a table of random numbers. The list of all students and their identification numbers was then forwarded to the clinical personnel responsible for the treatment and surveillance of occupational exposures at the hospitals affiliated with the University of California, San Francisco. The clinicians (who already knew the names of exposed students because they provided postexposure clinical care) extracted relevant data, including exposure history, type of exposure, and the results of baseline and follow-up tests for bloodborne viruses, from the student's confidential exposure record. No other data on exposures were available from the student health service or other providers. The exposure data were linked to the students' identification numbers in a computer database. To maintain confidentiality, the clinicians then deleted the student names from the database and returned the exposure data to the study personnel without including personal identifiers.

The protocol for this study was approved by the University of California, San Francisco, Committee on Human Research.

School of Medicine Curriculum

All medical students at the University of California, San Francisco, School of Medicine are required to participate in the same 10 core clerkships (totaling 52 weeks) during the third and fourth years of medical school. Eight of these clerkships are in anesthesia, family and community medicine, obstetrics–gynecology, medicine, neurology, pediatrics, psychiatry, and surgery and surgical specialties; 1 is a medicine subinternship; and 1 is another subinternship in which the student has primary responsibility for patient care (more than two thirds of students elect to take emergency medicine). Schedules are determined by lottery, and the sequence and location of clerkships vary widely. All students in the years studied rotated through all four of the San Francisco hospitals affiliated with the University of California, San Francisco.

Training in Exposure Prevention

In June 1989, the University of California, San Francisco, implemented a requirement that all third-year medical students be trained in universal precautions and exposure prevention as a component of a 1-week introduction to clerkships. First conceived to provide clinical skills and training in universal precautions, this program has evolved into a mini-course intended to improve the experience and performance of third-year medical students in clerkships. The course is taught by clinical faculty and fourth-year medical students. Through lectures; small group seminars; panel discussions; and hands-on practice with phlebotomy, intravenous catheter insertion, arterial blood sampling, and blood culture techniques, students learn the essentials of bedside clinical procedures in a safe, low-stress environment. All students watch the same videotape and hear discussions about universal precautions and ex-

Table 1. Graduation Year and Graduating Class Size of Students Who Reported Occupational Exposures

Graduation Year	Students	Students with Occupational Exposures	Occupational Exposures
	←	*n*	→
1990	138	9	9
1991	135	14	15
1992	143	22	25
1993	163	29	33
1994	151	20	21
1995	155	16	17
1996	137	9	9
Total	1022	119	129

posure prevention provided by occupational health and infection control nurses. Since 1993, this course has also included hands-on instruction in the use of safer needle devices for phlebotomy and intravenous catheter insertion. Each year, the students rate the course as excellent.

Assessment of Underreporting

Previous investigators (2, 4, 6) have established that occupational exposures among housestaff and medical students are substantially underreported. We hypothesized that the needlestick hotlines would increase the rate of reporting once students became comfortable with these confidential services. To estimate the degree of underreporting, we conducted anonymous surveys of medical students to ascertain the number of exposures sustained and the proportion of exposures reported to the hotlines. Students in the class of 1991 were queried in the winter of 1990 (just as the needlestick hotline was implemented), and students in the class of 1996 were queried just before graduation in June 1996. The anonymous questionnaires were distributed by the Office of Curricular Affairs.

Statistical Analysis

The proportion of exposed students was defined as the number of students reporting one or more exposures divided by the number of students enrolled at the University of California, San Francisco, School of Medicine during the study period. For each student who had multiple exposures, one exposure was chosen by using a table of random numbers to avoid the possibility of bias toward students who reported or sustained more exposures. Categorical data were compared by using the chi-square test. Comparisons with a P value less than 0.05 (two-tailed) were considered statistically significant.

Results

One thousand twenty-two medical students were enrolled in the University of California, San Francisco, School of Medicine classes of 1990 through 1996 (**Table 1**). Of these students, 119 (11.7% [95% CI, 9.0% to 15.2%]) reported one or more occupational exposures to the needlestick hotlines. Only 10 students (2%) reported two exposures. Most occupational exposures were caused by needle punctures (**Table 2**).

Infections with Bloodborne Pathogens

This study was not designed to evaluate the incidence of infection with bloodborne pathogens, but no students who reported eligible exposures were known to have acquired HIV, hepatitis C virus (HCV), or hepatitis B virus (HBV) infection. In 1993, the medical school purchased disability insurance for all students to provide coverage for occupational infections. After 4 years of experience with the same insurance broker, no disability claims had been made by medical students for any illness, including illnesses resulting from occupational exposures to infectious pathogens (Woshkowiak W. Personal communication). However, less than 50% of students had postexposure tests to detect new infections. Our study design did not allow us to link source-patient test results with student exposures; therefore, the number of students who actually needed follow-up testing could not be determined. We do know, from the hotline service clinicians, that some students who were exposed to bloodborne pathogens were not adherent to scheduled follow-up visits, especially when they rotated to new facilities.

Risk Factors for Exposure

Of the reported occupational exposures, 82% occurred on four services: obstetrics–gynecology, surgery, medicine, and emergency medicine (**Table 3**). Exposures occurred throughout the academic year. One fourth of exposures occurred during a first clerkship, but more than half ($n = 69$) were sustained during a fourth-year senior clerkship or subinternship. Among students who had exposures, no differences were seen in the proportions of those who sustained needle punctures in the seven graduating classes ($P > 0.2$) or at the various teaching sites ($P = 0.11$). Of the 10 students who had two

Table 2. Types of Occupational Exposures Sustained by Medical Students

Type of Exposure	Single Exposure per Student ($n = 119$)	All Exposures ($n = 129$)
	n (%)	
Needlestick	71 (61)	75 (58)
Splash	23 (20)	26 (20)
Laceration	13 (11)	14 (11)
Unknown	12 (8)	14 (11)
Total	119 (100)	129 (100)

Table 3. Incidence of Exposure during Each Clerkship Rotation*

Rotation	Students Taking Rotation	Exposures†	Exposure Incidence‡
	%	*n* (%)	
Emergency department elective	52	25 (21)	4.7
Obstetrics–gynecology subinternship	6	2 (1.7)	3.3
Surgery subinternship	16	5 (4.2)	3.1
Medicine subinternship	95	17 (14.3)	1.8
Obstetrics–gynecology core clerkship	100	22 (18.5)	1.4
Surgery core clerkship	100	15 (12.6)	0.7
Neurology core clerkship	100	6 (5.0)	0.6
Medicine core clerkship	100	11 (9.2)	0.5
Pediatrics core clerkship	100	3 (2.5)	0.2
Psychiatry core clerkship	100	3 (2.5)	0.2
Family and community medicine core clerkship	100	2 (1.7)	0.1
Anesthesia core clerkship	100	2 (1.7)	0.1

* Six exposures were sustained on rotations taken by less than 2% of students and do not appear in this table.
† The percentages listed are percentages of the total number of exposures ($n = 113$).
‡ Number of exposures per 100 student-months.

exposures, all sustained their first and second exposures on different clerkships. The rate of occupational exposure was decreased in the last three graduating classes studied ($P = 0.02$ for comparison of the frequency distribution of exposures in the 7-year study sample).

Detailed exposure information was available for the 77 exposures that were reported after a standardized exposure report form was introduced at all employee health services in January 1993. These exposures resulted from 42 needle punctures, 10 injuries caused by sharp devices other than needles, and 25 mucosal splashes. Of the 42 needle punctures, 18 (43%) were caused by suture needles, 13 (31%) were caused by hollow-bore injection needles, 5 (12%) were caused by vacuum tube collection needles, 4 (9.5%) were caused by winged steel blood collection needles, 1 (2.3%) was caused by a catheter stylet, and 1 (2.3%) was caused by a spinal needle. The 24 nonsuture needles that caused injury were used for various procedures, including blood sampling (50%) and injections (29%). Some injuries (38%) occurred while a procedure was being done, but most (62%) occurred after a needle was used for its intended purpose but before it was properly disposed of. Six of the 24 injuries caused by nonsuture needles (25%) were caused by "safer" needle devices; 3 occurred during a procedure, and 3 occurred after the device was used but before the safety feature was activated. No injuries were associated with failure of the safety device.

The 77 exposures reported after January 1993 occurred in a wide variety of hospital settings, but operating suites (26%), emergency departments (23%), and labor and delivery units (9%) were the most common locations. Six of the 18 injuries caused by suture needles (33%) were inflicted by health care workers other than the student who sustained the exposure. Similarly, 5 of the 14 injuries (36%) caused by needles or other sharps during operating room procedures were inflicted by other personnel in the surgical field. Ten of the 77 exposures (13%) occurred in students who had been on duty for at least 16 hours; 14% occurred in students who had had less than 4 hours of sleep in the past 24 hours; and 17% occurred in students who had been on duty for at least 6 consecutive days.

Reporting Results

Forty-two percent of the class of 1991 responded to the first underreporting survey, and 45% of the exposures described by these students were reported to a needlestick hotline. The most common reasons cited for not reporting an exposure to the hotline were 1) the exposure was too trivial, 2) the exposure occurred before the hotline was implemented, and 3) the exposure was reported to the student health service. Nine responders stated that they had reported an exposure to a hotline, but the hotline clinicians provided data on 12 student exposures.

Eighty-five students (62%) from the class of 1996 responded to the final underreporting survey. Seventeen of these 85 students (20%) stated that they had sustained an occupational exposure, and 11 of these 17 exposures (65%) were reported to a hotline.

Discussion

Our study provides longitudinal data about the frequency of reported blood exposures in a large sample of medical students, and it shows that a significant proportion of students remain at risk for these exposures despite a strong institutional commitment to training and targeted prevention interventions. The risk for infection among students is a product of three probabilities: the risk for an exposure, the prevalence of infection in the source-patient population, and the probability of transmission attributable to the exposure. The prevalence of infection in patients cared for in teaching hospitals varies widely but is usually highest in urban hospitals, especially in such cities as San Francisco, where HIV infection and injection drug use are common in the community. At San Francisco General Hospital, where 55% of the student exposures occurred, 34% of source patients have antibodies to HCV, 23% have HIV infection, and 2.3% have HBV antigenemia (8). The average risk for infection associated with parenteral exposure to HIV is approximately 0.3%, although recent data suggest that postexposure prophylaxis may significantly decrease this risk (9, 10). Transmission of HCV occurs after approx-

imately 1.8% of needle punctures involving contaminated blood and is even more common when the source patient has circulating virus detected by polymerase chain reaction (9). The risk for transmission of HBV to those susceptible to infection exceeds 30% when the source patient has hepatitis B e antigen (HBeAg), a marker of high circulating virus titer, but it is still substantial even when HBeAg is not present (9). Fortunately, the requirement that medical students be immunized against HBV at the University of California, San Francisco, and elsewhere has dramatically reduced the risk for acquiring HBV infection during training (11–13).

The number of accidents did not seem to decrease with clinical experience; more than half of exposures occurred during the senior year. Our hypothesis that exposures would be fewer after the completion of clerkships involving more clinical procedures (obstetrics–gynecology, surgery, and medicine) was not supported by our findings.

Our underreporting surveys show that the true number of exposures sustained by students is even higher than the estimate based on reported exposures. However, our reporting rate seems to have increased from 45% to 65% between 1989 and 1996, coincident with implementation of the needlestick hotlines, and is higher than reporting rates in other institutions (17% [2] to 40% [6]) and among other health care providers (40% [4]). Access to the needlestick hotlines and confidence in the quality and confidentiality of the services provided may have contributed to the higher reporting rates at our institution. Even so, further efforts to improve reporting are warranted. The fact that exposures continued to be underreported may have more to do with role models among faculty and housestaff than with the systems provided for education and counseling. Students report that they are discouraged from leaving the operating room after an accident except to rescrub and change gloves. They also report being left to perform procedures without supervision on very sick patients in the emergency department, where they are the least well-trained provider. For the individual student, prompt reporting is essential for appropriate risk assessment, medical care (including postexposure chemoprophylaxis), psychological counseling, and follow-up to document infection status. For the institution, complete exposure surveillance is necessary to identify high-risk activities and settings, define new targets for preventive interventions, monitor the success or failure of these interventions, and reduce legal liability.

The lack of HIV, HBV, or HCV seroconversion in our cohort of medical students is not completely reassuring, particularly because ascertainment of infection-free status was not complete for all 119 exposed students. Given our relatively small sample, the upper limit of the 95% CI for the rate of infection is still 2.5% (14). Our study was not designed to measure the prevalence of viral infections among source patients and the subsequent risk for transmission of pathogens, but many exposures involved blood from source patients with documented HIV, HCV, and HBV infection. The relatively poor rate of follow-up testing for bloodborne infections among exposed students is worrisome and suggests that some new infections could have been missed. Contacting students for follow-up testing is often difficult, given the frequent relocation of students. Improved coordination or centralization of postexposure follow-up among the involved health services is clearly needed to facilitate completion of the testing protocol.

Of the occupational exposures to medical students, 61% were caused by needle punctures, a rate similar to that seen in other medical schools (57% [6] and 46% [15]). In general, needle punctures pose the highest risk for transmission of bloodborne pathogens (16). Needles used for phlebotomy, visibly bloody needles, and deep needle punctures are independent predictors of risk for HIV infection (10). In the subset of exposures for which detailed information was available, 50% of the implicated needles had been used for phlebotomy. Preventing this type of injury must assume the highest priority. Recent data have shown that safer needle devices can prevent phlebotomy-associated injuries (17). Although our data do not prove that these devices confer a direct benefit, the reduced frequency of injury noted in the past 3 years does coincide with the widespread implementation of safer needle devices for phlebotomy and placement of intravenous catheters at the hospitals affiliated with the University of California, San Francisco (18–20). Nevertheless, these devices are not a panacea; at best, they only prevent accidents that would otherwise have occurred when the needle was used for its intended purpose, and even then they will do so only if properly activated.

Given the plethora of safety devices now on the market, most of which require manipulation to activate the safety feature, it is imperative that students be thoroughly trained—with hands-on practice—in the use of these products. At the University of California, San Francisco, a safety device formulary committee has been created to facilitate the implementation of identical safety devices in all affiliated institutions. This approach avoids the need for training each time the student moves to a new location, and it is intended to improve compliance with device activation. It may be prudent to require "certification" in the use of these devices before students and housestaff are allowed to begin clinical care.

The data from our survey suggest other targets

Table 4. Comprehensive Management and Prevention Checklist for Blood-Borne Pathogen Exposure*

- Postexposure care
  - Exposure reporting and immediate treatment
    - Implement a needlestick hotline (or similar rapid response system) for initial reporting of student exposures to expert clinicians 24 hours a day, 7 days a week.
    - Ensure quick access to antiretroviral treatment after exposures known or likely to involve HIV.
    - Provide HBV vaccine (unless the student is a documented nonresponder to this vaccine) and HBIG for susceptible students when the exposure is known or suspected to involve HBV.
  - Risk assessment and counseling
    - Evaluate source patients to document HIV, HBV, and HCV infection status.
    - Document the exposure severity (route, volume, injury depth).
    - Document the exposure circumstances (service, location, device, activity, mechanism) by using a standard report to facilitate ongoing surveillance.
    - Provide supportive counseling and advice for preventing transmission to others until infection is excluded.
  - Ascertainment of outcome
    - Perform baseline tests to exclude preexisting HIV, HBV, or HCV infection (or bank serum specimens) when the exposure poses a transmission risk.
    - Encourage cooperation among teaching hospitals and student health services to facilitate access to follow-up testing of students exposed to bloodborne pathogens who rotate to a new site.
    - Document completion of follow-up and final infection status.
- Exposure surveillance system
  - Aggregate exposure data (without personal identifiers) to identify high-risk areas, services, devices, and activities.
  - Report aggregate data to the medical school, affiliated hospitals, and clinical services.
  - Identify and implement targeted prevention interventions.
  - Monitor trends in exposure epidemiology.

* HBIG = hepatitis B immune globulin; HBV = hepatitis B virus; HCV = hepatitis C virus.

for prevention efforts (**Table 4**). The emergency department is the site of many invasive bedside procedures, and it is clearly a high-risk location for serious blood exposures. Administrative issues (relying on medical students to perform bedside procedures in the absence of dedicated phlebotomy and catheter-placement teams), ergonomic issues (crowding and lack of easy access to sharps-disposal containers), and clinical issues (competing priorities in the care of critically ill patients that detract from safety standards and proper supervision) may contribute to risk in this setting. Similar issues are likely to contribute to the high frequency of intraoperative exposures. The fact that a significant proportion of injuries sustained during surgical procedures was inflicted by members of the surgical team other than the exposed student suggests that surgical attending physicians and senior residents must be held accountable for the safety of students in the surgical field (3).

Our data also show that some exposed students had worked long hours for many consecutive days with little sleep. The absence of a comparison group of students who did not sustain injuries precludes conclusions about the role of these factors in the occurrence of injury. Nevertheless, common sense dictates that fatigue and stress impede the learning and safe practice of medical procedures. Greater enforcement of requirements for scheduled days off and adequate opportunity for sleep seem warranted.

Even more important than better educational programs and safer needle products is the necessary change in attitudes and culture that will affect the learning environment of medical students. The fact that 20% of students are at risk for exposure to bloodborne pathogens that cause fatal disease may be the tip of the iceberg in medical education. Other risks to mental and physical health have been discussed in the literature on medical education (21–23). The cogent measures for error prevention described by Leape (24) should be adopted by hospital and medical school leaders. Needlesticks are "errors of action" that can be reduced through the creation of safety procedures that minimize the chance for errors and by continual training sessions that require certification in these procedures. Needle safety devices are only one step in this process. The most important and most difficult step is the identification of mistakes; this must be done before systems can be corrected. As Leape (24) commented, "Errors must be accepted as evidence of system flaws not character flaws." Until the medical profession can look at errors as "gems" for improvement rather than as opportunities for malpractice suits, we will continue to teach students to hide their mistakes. This is dangerous for the future physicians whom we train and for our patients.

Our study was designed to determine the effect of training and reporting systems for occupational exposures among medical students. One limitation is the lack of a system for identifying all exposures: We relied on students' self-reports to needlestick hotlines. Although our graduation surveys suggest that the reporting rate increased from 45% to 65% between 1989 and 1996, many exposures occurred for which we have no data. Another limitation is that this study is from only one school with a small cohort of reported exposures. Studies that compare experiences at different institutions could be designed to identify systems that prevent exposures. Finally, this study was not designed to determine seroconversion rates. It would be reassuring to know that none of the students who had exposures acquired infection; unfortunately, follow-up testing was done on only 50% of the cohort.

Medical students are often eager to perform procedures but lack the judgment and experience to determine whether they have the requisite skills to do so safely. Moreover, they are the least "empowered" members of the health care team and may fear negative sanctions if they refuse to perform tasks for which they are not adequately prepared. Attending physicians and senior housestaff must be made responsible for ensuring that students are capable of performing procedures safely before ex-

pecting them to do so without supervision. It is our responsibility as medical educators to provide a safe learning environment for students before they face the risks of direct patient care. The era of "see one, do one, teach one" is long past.

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References

1. **Tereskerz PM, Pearson RD, Jagger J.** Occupational exposure to blood among medical students. N Engl J Med. 1996;335:1150-3.
2. **Resnic FS, Noerdlinger MA.** Occupational exposure among medical students and house staff at a New York City medical center. Arch Intern Med. 1995;15:75-80.
3. **Vergilio JA, Roberts RB, Davis JM.** The risk of exposure of third-year medical students to human immunodeficiency virus in the operating room. Arch Surg. 1993;128:36-9.
4. **Mangione CM, Gerberding JL, Cummings SR.** Occupational exposure to HIV: frequency and rates of underreporting of percutaneous and mucocutaneous exposures by medical housestaff. Am J Med. 1991;90:85-90.
5. **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.
6. **Koenig S, Chu J.** Medical student exposure to blood and infectious body fluids. Am J Infect Control. 1995;23:40-3.
7. **Mansour AM.** Which physicians are at high risk for needlestick injuries? Am J Infect Control. 1990;18:208-10.
8. **Evans SE, Fahrner R, Gerberding JL.** HIV, HBV, and HCV prevalence among source patients reported to the San Francisco General Hospital Needlestick Hotline [Abstract]. In: Programs and Abstracts of the 34th Annual Meeting of the Infectious Diseases Society of America, New Orleans, LA, 1996.
9. **Gerberding JL.** Management of occupational exposures to blood-borne viruses. N Engl J Med. 1995;332:444-51.
10. **Cardo DM, Culver DH, Ciesielski CA, Srivastava PU, Marcus R, Abiteboul D, et al.** A case-control study of HIV seroconversion in health care workers after percutaneous exposure. Centers for Disease Control and Prevention Needlestick Surveillance Group. N Engl J Med. 1997;337:1485-90.
11. 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.
12. **Diekema DJ, Albanese MA, Densen P, Doebbeling BN.** Student health policies of U.S. medical schools. Acad Med. 1996;71:1090-2.
13. **Liaison Committee on Medical Education.** Functions and Structure of a Medical School: Standards for Accreditation of Medical Education Programs Leading to the M.D. Degree. Washington, DC: Association of American Medical Colleges; 1995:75-80.
14. **Hanley JA, Lippman-Hand A.** If nothing goes wrong, is everything all right? Interpreting zero numerators. JAMA. 1983;249:1743-5.
15. **Diekema DJ, Alabanese MA, Schuldt SS, Doebbeling BN.** Blood and body fluid exposures during clinical training: relation to knowledge of universal precautions. J Gen Intern Med. 1996;11:109-11.
16. **Lewis FR Jr, Short LJ, Howard RJ, Jacobs AJ, Roche NE.** Epidemiology of injuries by needles and other sharp instruments. Minimizing sharp injuries in gynecologic and obstetric operations. Surg Clin North Am. 1995;75:1105-21.
17. 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.
18. **Hanrahan A, Reutter L.** A critical review of the literature on sharps injuries: epidemiology, management of exposures and prevention. J Adv Nurs. 1997; 25:144-54.
19. **Gerberding JL, Lewis FR Jr, Schecter WP.** Are universal precautions realistic? Surg Clin North Am. 1995;75:1091-104.
20. **Orenstein R, Reynolds L, Karabaic M, Lamb A, Markowitz SM, Wong ES.** Do protective devices prevent needlestick injuries among health care workers? Am J Infect Control. 1995;23:344-51.
21. **Sheehan KH, Sheehan DV, White K, Leibowitz A, Baldwin DC Jr.** A pilot study of medical student "abuse." Student perceptions of mistreatment and misconduct in medical school. JAMA. 1990;263:533-7.
22. **Silver HK, Glicken AD.** Medical student abuse. Incidence, severity, and significance. JAMA. 1990;263:527-32.
23. **Christakis DA, Feudtner C.** Temporary matters. The ethical consequences of transient social relationships in medical training. JAMA. 1997;278:739-43.
24. **Leape L.** Error in medicine. JAMA. 1994;272:1851-7.