Transmission of Human Immunodeficiency Virus Infection in the Surgical Setting

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Abstract

The emergence of the human immunodeficiency virus (HIV) has highlighted the need for orthopaedic surgeons to understand the epidemiology of percutaneous injuries and other blood exposures in the surgical setting. The American Academy of Orthopaedic Surgeons and the Centers for Disease Control and Prevention have worked to increase understanding and prevent transmission of blood-borne viral diseases in orthopaedic surgery. This article addresses the risk of HIV transmission in the surgical setting, with a focus on surveillance efforts to monitor the extent of occupational HIV infection, specific risk factors, and postexposure management. Health-care worker–to–patient transmission and patient-to-patient transmission are also addressed.

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Human immunodeficiency virus (HIV) infection has been recognized in the United States for over a decade. The emergence of HIV infection, as well as other blood-borne viral diseases, has given emphasis to the need to understand the epidemiology of percutaneous injuries and other blood exposures in the surgical setting. The American Academy of Orthopaedic Surgeons (AAOS) has taken a leadership role in the development of precautions to prevent transmission of blood-borne diseases in orthopaedic surgery. In 1991, the Centers for Disease Control and Prevention (CDC) and the AAOS performed a serosurvey to determine the prevalence of HIV infection among orthopaedic surgeons.[1] New information on the risk of health-care worker–to–patient and patient-to-patient transmission and on the efficacy of chemoprophylaxis by health-care workers after an HIV exposure has created a need for an update.

Transmission From Patients to Health-Care Workers

Surveillance Update

Acquired immunodeficiency syndrome (AIDS) surveillance has been an important mechanism for identifying cases of occupationally acquired HIV infection among health-care workers in the United States. In 1991, surveillance efforts were expanded to include reporting of persons with suspected occupationally acquired HIV infection who did not meet the AIDS case definition. In this system, infections in health-care workers are classified as either "documented" or "possible" cases of occupational HIV transmission.[2] Health-care workers with documented occupationally acquired HIV infection have evidence of HIV seroconversion temporally associated with an occupational percutaneous,

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mucous membrane, or cutaneous exposure to blood, bloody body fluids, or laboratory specimens. Health-care workers with possible cases of occupationally acquired HIV infection have reported a past occupational exposure to blood, body fluids, or laboratory specimens containing HIV, but seroconversion to HIV could not be temporally associated with an occupational exposure.

Through December 1995, there were reports of 151 health-care workers with occupationally acquired HIV infection; 49 were classified as having documented and 102 as having possible occupational transmission (Table 1).[2] Of the 49 with documented occupational transmission, 42 had percutaneous injuries, 5 had mucocutaneous exposures, and 1 had concurrent percutaneous and mucocutaneous exposures; in the remaining case, the route of exposure was unknown. Of their exposures to HIV, 44 involved blood; 1, visibly bloody fluid; 1, an unspecified fluid; and 3, concentrated virus in a laboratory.

All of the documented seroconversions from percutaneous exposures to date have occurred after an injury with a hollow-bore needle or other sharp object, such as a lancet, glass, or scalpel. No seroconversions have been documented after injury with solid suture needles.

HIV Seroprevalence Surveys of Health-Care Workers

Seroprevalence surveys can supplement national surveillance in monitoring HIV infection among health-care workers. Two such surveys have been conducted among surgeons. The first was an anonymous, voluntary HIV serosurvey conducted jointly by the CDC and the AAOS, involving 3,420 orthopaedic surgeons attending the 1991 AAOS annual meeting.[1] Of these, 3,267 reported only occupational risk factors for HIV infection, and none was positive for HIV antibody. The average surgeon in this group had been in practice 18 years, including nearly 4 years in an area of high AIDS incidence. Each performed an average of 28 surgical procedures per month. Collectively during their careers, they reported performing more than 9,000 procedures on patients known to have been infected with HIV. Two (1.3%) of the 153 orthopaedic surgeons who self-reported behavioral risk factors for HIV infection tested positive for HIV antibody.

The second study, also an anonymous, voluntary serosurvey, was conducted during 1991–1992 by Panlilio et al,[3] who surveyed 770 hospital-based surgeons (general, obstetrics/gynecology, and orthopaedic) who worked in areas of moderate to high HIV prevalence. Of the 770 surgeons, 662 (86%) reported performing procedures (mean number, 32) on patients with HIV infection or AIDS and sustaining an average of two percutaneous injuries since 1978 involving patients with HIV infection or AIDS. In this study, 1 (0.1%) of the 740 surgeons who reported only occupational risk factors was found to be infected with HIV. This surgeon had practiced general surgery for at least 25 years before the serosurvey and reported sustaining three percutaneous injuries involving patients with HIV infection or AIDS since 1978. Of the 20 participants who reported nonoccupational HIV risk factors and the 10 who did not respond to the risk-factor question, none was HIV-positive.

Table 1
US Health-Care Workers With Documented and Possible Occupationally Acquired AIDS/HIV Infection Through December 1995*

	No. of Workers With Occupational Transmission	
Occupation	Documented	Possible
Dental worker, including dentist	…	7
Embalmer/morgue technician	…	3
Emergency medical technician/paramedic	…	9
Health aide/attendant	1	12
Housekeeper/maintenance worker	1	7
Laboratory technician, clinic	15	15
Laboratory technician, nonclinical	3	0
Nurse	19	24
Physician, nonsurgical	6	10
Physician, surgical	…	4
Respiratory therapist	1	2
Technician, dialysis	1	2
Technician, surgical	2	1
Technician/therapist, other than those listed above	…	4
Other health-care occupations	…	2
Total	**49**	**102**

*Reprinted from Centers for Disease Control and Prevention: *HIV/AIDS Surveillance Rep*1995;7:21.

Seroprevalence studies among other types of health-care workers have had similar findings, with HIV infection rates of less than 1 per 1,000 workers tested.[4-6]

Risk of HIV Infection After Exposure

A health-care worker's risk of occupationally acquired HIV infection depends on several factors, including the prevalence of HIV in the patient population, which varies widely within the United States; the nature and frequency of occupational blood contact; and the risk of HIV transmission after a single contact with blood.

On the basis of prospective surveillance of more than 3,000 exposed health-care workers, the risk of seroconversion after a single percutaneous exposure to HIV-infected blood is approximately 0.3%.[7] This rate reflects an averaging of data related to different types of percutaneous exposures from source patients in various stages of HIV disease. It is likely that there are subsets of needle-stick injuries that are associated with seroconversion rates both higher and lower than 0.3%.

A recent retrospective case-control study conducted to assess potential risk factors influencing seroconversion after percutaneous exposure to HIV-infected blood[8] found that the risk was increased if the exposure was associated with any of three factors: (1) The risk increased if the exposure involved a larger quantity of blood, indicated by use of a device visibly contaminated with the patient's blood, a procedure in which a needle had been placed directly in a patient's vein or artery, or a deep injury. These findings are in agreement with laboratory studies that suggest that more blood is transferred by deeper injuries and by hollow-bore needles (especially those of larger gauges) compared with solid needles.[9,10] (2) The risk increased if there was exposure to blood from a source patient with a terminal illness. This finding probably reflects the higher titer of HIV in blood late in the course of AIDS, as well as other factors, such as the presence of a syncytium-inducing strain of HIV (i.e., a strain of HIV that produces characteristic cytopathic changes, including formation of multinucleated giant cells, or syncytia, in peripheral blood mononuclear cells), which has been associated with rapid progression of HIV infection. (3) Postexposure was associated with a higher risk of transmission if zidovudine (the new designation for azidothymidine, or AZT) was not used.

Data from 21 prospective studies of health-care workers worldwide include only one seroconversion among 1,107 mucous membrane exposures[11]; the affected worker sustained mouth, eye, and hand contact with a large amount of blood from an asymptomatic HIV-positive patient. On the basis of the aggregated data from these studies, the risk after a mucous membrane exposure has been estimated at 0.09%.[11] Although there have been case reports of HIV infection after cutaneous contact with HIV-infected blood, this risk has not been well quantified, since there has been no instance of seroconversion in any of the health-care workers enrolled in prospective studies who had an isolated skin exposure.

Epidemiology of Blood Contact

Prospective studies in surgery and obstetrics have clarified the nature, frequency, and preventability of blood contacts among health-care workers and patients.[12-14] In 1990, Tokars et al[12] observed 1,382 procedures in five surgical specialties (general, orthopaedic, gynecologic, cardiac, and trauma) in two urban and two suburban US hospitals in areas of high AIDS incidence. A total of 99 percutaneous injuries occurred in 95 (7%) of the procedures. Orthopaedic procedures had a 4% percutaneous injury rate. The majority (77%) of the injuries were related to suturing. Of the 99 injuries, 62 (63%) affected the nondominant hand (in most cases, the distal forefinger). Eighty-eight (89%) of the injuries were sustained by resident or attending surgeons. In 28 (32%) of these 88 injuries, the object that caused the injury recontacted the patient. Multivariate analysis revealed that the type of procedure performed, its duration, and stabilizing tissue with fingers instead of an instrument while suturing were independent risk factors for injury.

Gerberding et al[14] observed 1,307 surgeries in a prospective study during 1988. Multivariate analysis disclosed that independent risk factors for blood exposure were (1) procedures that lasted more than 3 hours, (2) more than 300 mL of blood loss, and (3) vascular or intra-abdominal procedures.

Neither knowledge of the patient's HIV-seropositive status nor knowledge of risk factors for HIV infection affected the rate of health-care worker exposure in either of these studies.

Aerosolized Blood

One question that has attracted attention is whether HIV can be transmitted to health-care workers by aerosolized blood (i.e., particles of blood less than 100 µm in diameter, which may remain suspended in air for extended periods). Transmission of blood-borne pathogens by aerosol would require the generation of aerosolized particles of blood, the presence of infective blood-borne pathogens in these aerosolized particles, and the depo-

sition of a sufficient number of infective blood particles in the respiratory tract or on the mucous membranes of a susceptible host. Biologic or epidemiologic evidence that HIV can be transmitted by aerosols via the respiratory route does not exist currently.[15] One laboratory-simulated study that used blood to which HIV had been added showed that some surgical power instruments produced vapors that contained infective HIV; however, the clinical significance of this finding is not certain.[16]

Serosurveys of surgeons and dentists do not suggest a risk of aerosolized HIV transmission.[15] In the CDC-AAOS serosurvey of orthopaedic surgeons,[1] 1,201 of the orthopaedic surgeons without nonoccupational risk factors reported having participated in procedures on patients with HIV infection or AIDS without ever having used a self-contained air supply ("space suit") or other device to prevent inhalation of aerosols. Although the proportion of these procedures in which power instruments were used was unknown, power instruments are used frequently in orthopaedic procedures, and many of the study participants may have been exposed to blood or tissue aerosols produced by these instruments. All of the 1,201 surgeons were HIV-seronegative.

Prevention of Occupational Exposures

Infection-Control Practices

Because blood is the single most important source of HIV infection in the health-care setting, risk reduction can be accomplished most effectively by reducing the frequency of blood exposures among health-care workers. Exposure prevention requires a combination of engineering controls or safety devices, personal protective equipment, safer techniques and work practices, and training in and enforcing compliance with their proper use.

In 1987, the CDC first recommended universal precautions to prevent contact with blood, certain other body fluids, and tissues of all patients.[17] These recommendations, coupled with the detailed AAOS recommendations[18] published in 1989 and the subsequent blood-borne pathogen standard of the Occupational Safety and Health Administration, have become an important component in the overall strategy to prevent occupational blood contact among orthopaedic surgeons. The use of universal precautions by health-care workers has been shown to be efficacious in preventing blood contacts.[19]

In 1996, the Hospital Infection Control Practices Advisory Committee of the CDC published new guidelines for isolation precautions in hospitals.[20] Two tiers of precautions were outlined. The first tier, "Standard Precautions," synthesizes the major features of universal precautions and body-substance isolation and is intended to prevent transmission of many non-blood-borne and blood-borne pathogens, including HIV. These standard precautions apply to blood; all other body fluids, secretions, and excretions (except sweat); nonintact skin; and mucous membranes.

The second tier, "Transmission-Based Precautions," for patients documented or suspected to be infected with highly transmissible or epidemiologically important pathogens or diseases (e.g., pulmonary tuberculosis, multi-drug-resistant organisms, and group A *Streptococcus* pharyngitis and pneumonia), includes additional precautions beyond standard precautions needed to interrupt transmission in hospitals. There are three types of transmission-based precautions: air-borne precautions, droplet precautions, and contact precautions. Transmission-based precautions are to be used in addition to standard precautions.[20]

Safety Devices

New devices with features intended to reduce the likelihood of percutaneous injury by hollow and solid-bore needles and scalpels are increasingly available. However, few have been studied extensively.

Robert et al[21] evaluated the efficacy of the blunt-tip suture needle in reducing percutaneous injuries during gynecologic surgery procedures in three New York City hospitals. During the study period (1993–1994), blunt-tip suture-needle use increased from 1% to 55% of all suture needles used. This increase was associated with a significant decrease in the rate of suture-related injuries, from 5.8 to 1.0 per 100 procedures. Injury rates per 1,000 needles used were 2.1 and 14.2, respectively, for standard and straight needles; no injuries occurred with blunt-tip needles. In 4% of 656 procedures in which blunt-tip suture needles were used, surgeons reported difficulty in penetrating tissue; tissue tearing, needle slippage, and bleeding were reported in fewer than 1% of the procedures.

Preliminary data from a study of user-activated safety devices for phlebotomy by Short et al[22] in 1995 showed that percutaneous injury rates were reduced 40% overall, from 4.3 per 100,000 phlebotomy procedures with standard devices to 2.6 with safety devices. For vacuum-tube blood-collection needles alone, injury rates were reduced 77%, from 1.6 to 0.4 per 100,000 procedures. Although an inspection of sharps-disposal containers showed that 92% of phlebotomy devices were safety devices,

safety features were activated for only 74% of safety devices.

Personal Protective Equipment

Several studies conducted in surgical settings have shown that wearing more than one pair of gloves reduced the frequency of blood-hand contact.[5,6,14,21,23] For example, Tokars et al[23] found that the rate of blood-hand contact was 72% lower for double-gloved surgeons than for single-gloved surgeons. Besides decreasing the incidence of blood-hand contact, use of double gloves also may reduce the volume of blood associated with percutaneous injury; laboratory studies have shown that when hollow-bore needles are passed through two pairs of gloves instead of one, smaller volumes of blood are transferred.[10]

Selection of gowns, masks, and protective eyewear should be guided by knowledge about the nature and frequency of blood contact; the type, duration, and estimated blood loss associated with a procedure; the occupation or role of the health-care worker during a surgical procedure; the worker's training and experience; and the cost of the equipment and its acceptability to the worker.[18,24,25] In a study of blood contact during surgical procedures, Tokars et al[23] found that the blood-face contact rate was significantly lower among surgeons who used face shields. Both the blood-face contact rate and the rate of use of face shields were highest on the orthopaedic service (111 of 117 surgeons who used face shields were orthopaedists). Among orthopaedists, blood-face contact was noted in none of the 111 face-shield users but in 74 (9%) of the 799 nonusers.

The AAOS Committee on Infections and others have made specific recommendations regarding personal protective equipment for surgical procedures.[18,24]

Surgical Techniques

Technique modification, including step-by-step minimization of sharps use, has been attempted for some surgical procedures.[24] The AAOS Committee on Infections and others have suggested specific techniques for decreasing exposures, including use of magnetic trays or basins to pass sharps, announcement of instrument passes, use of forceps or other instruments instead of fingers, and use of stapling or other nonsuture techniques during wound closure.[18]

Routine Testing of Patients

The US Public Health Service has recommended that voluntary and confidential HIV counseling and testing of patients in acute-care hospitals is useful for assisting in differential diagnosis of medical conditions, initiating early medical management of HIV infection, and informing infected persons and persons at risk for infection about behaviors that can prevent HIV transmission.[26] Such a program would encourage health-care workers to routinely ask patients about their risks for HIV infection and to offer HIV counseling and voluntary testing services to patients at risk. Although testing of patients has been proposed as a measure to minimize risk of HIV infection for surgical teams,[18] studies have not demonstrated the efficacy of testing for this purpose.[12,14]

Management of an Occupational Exposure to HIV

Detailed recommendations for management of exposures to blood and blood-borne pathogens have been published.[27,28] These include prompt reporting of the exposure to facilitate provision of necessary counseling and management, evaluation of the need for postexposure prophylaxis, testing of the source patient (with consent) for hepatitis B surface antigen and HIV antibodies, and serologic follow-up of the health-care worker. Postexposure testing of workers exposed to hepatitis C can also be considered for detection of both hepatitis C antibodies and evidence of hepatitis.[28] The confidentiality of the source patient and the health-care worker should be maintained.

Although failures of postexposure zidovudine therapy to prevent HIV infection in health-care workers have been documented,[7] a recent case-control study demonstrated that the use of the drug after percutaneous exposure to HIV-infected blood reduced the risk of subsequent HIV infection.[8]

In addition to the case-control study, two other pieces of information suggest a protective effect of postexposure zidovudine.[29] In a prospective trial in which the drug was administered to HIV-infected pregnant women and their infants, a direct effect of prophylaxis on the fetus and/or infant may have contributed to the observed 67% reduction in perinatal HIV transmission. The protective effect of zidovudine was only partly explained by reduction of the HIV titer in maternal blood. Postexposure prophylaxis also prevented or ameliorated retroviral infection in some studies in animals.

Accordingly, in June 1996 the US Public Health Service published updated recommendations for chemoprophylaxis (Table 2).[29] These recommendations are provisional, because they are based on limited data regarding the efficacy and toxicity of postexposure prophylaxis and the risk of HIV infection after different types of exposure. Because most occupational exposures to HIV do not result in infection transmission, potential

Table 2
Provisional Public Health Service Recommendations for Chemoprophylaxis After Occupational Exposure to HIV[*]

Type of Exposure	Source Material[†]	Antiretroviral Prophylaxis[‡]	Antiretroviral Regimen[§]
Percutaneous	Blood[¶]		
	Highest risk	Recommend	ZDV plus 3TC plus IDV
	Increased risk	Recommend	ZDV plus 3TC ± IDV[#]
	No increased risk	Offer	ZDV plus 3TC
	Fluid containing visible blood, other potentially infectious fluid, or tissue	Offer	ZDV plus 3TC
	Other body fluid (e.g., urine)	Do not offer	
Mucous membrane	Blood	Offer	ZDV plus 3TC ± IDV[#]
	Fluid containing visible blood, other potentially infectious fluid, or tissue	Offer	ZDV ± 3TC
	Other body fluid (e.g., urine)	Do not offer	
Skin[**]	Blood	Offer	ZDV plus 3TC ± IDV[#]
	Fluid containing visible blood, other potentially infectious fluid, or tissue	Offer	ZDV ± 3TC
	Other body fluid (e.g., urine)	Do not offer	

[*] Adapted from Centers for Disease Control and Prevention: Update: Provisional Public Health Service recommendations for chemoprophylaxis after occupational exposure to HIV. *MMWR Morb Mortal Wkly Rep* 1996;45:468-472.
[†] Any exposure to concentrated HIV (e.g., in a research laboratory or production facility) is treated as percutaneous exposure to blood with highest risk. "Other potentially infectious fluid" is defined as including semen, vaginal secretions, and cerebrospinal, synovial, pleural, peritoneal, pericardial, and amniotic fluids.
[‡] Recommendations are defined as follows: "Recommend" indicates that postexposure prophylaxis (PEP) should be recommended to the exposed worker with counseling. "Offer" indicates that PEP should be offered to the exposed worker with counseling. "Do not offer" indicates that PEP should not be offered because these are not occupational exposures to HIV.
[§] Regimens are as follows: ZDV = zidovudine, 200 mg three times a day; 3TC = lamivudine, 150 mg twice daily; IDV = indinavir, 800 mg three times a day (if IDV is not available, saquinavir may be used, 600 mg three times a day). Prophylaxis is given for 4 weeks. For full prescribing information, see package inserts.
[¶] "Highest risk" is defined as **both** a larger volume of blood (e.g., deep injury with large-diameter hollow needle previously in source patient's vein or artery, especially involving an injection of source patient's blood) **and** the presence of blood containing a high titer of HIV (e.g., source patient with acute retroviral illness or end-stage AIDS; viral load measurement may be considered, but its use in relation to PEP has not been evaluated). "Increased risk" is defined as **either** exposure to a larger volume of blood **or** the presence of blood with a high titer of HIV. "No increased risk" is defined on the basis of there being **neither** exposure to a larger volume of blood **nor** the presence of blood with a high titer of HIV (e.g., solid suture-needle injury from source patient with asymptomatic HIV infection).
[#] Possible toxicity of additional drug may not be warranted.
[**] For skin, risk is increased for exposures involving high titer of HIV, prolonged contact, an extensive area, or an area in which skin integrity is visibly compromised. For skin exposures without increased risk, the risk of drug toxicity outweighs the benefit of PEP.

toxicity must be carefully considered when prescribing postexposure prophylaxis.

Transmission From Health-Care Workers to Patients

Transmission of HIV from an infected dentist to six patients in a Florida dental practice has been reported.[30] Excluding those instances, as of January 1995, the CDC was aware of investigations in which HIV test results were known for approximately 22,171 patients treated by 51 HIV-infected health-care workers.[31] No seropositive persons were found among 13,059 tested patients from the practices of 37 of the health-care workers (none of them surgeons). As for the remaining 14 health-care workers, 9,108 of their patients were tested; 113 were seropositive, but no instance of HIV transmission to patients was documented (Table 3).

Although data from these retrospective investigations are reassuring, they have substantial limitations. The HIV test results were available for only about 17% of patients of the HIV-infected health-care workers. Data on procedures were available for only 19% of the

Table 3
Epidemiologic and Laboratory Follow-up of 113 HIV-Infected Patients From the Practices of HIV-Infected Health-Care Workers*

	No. of Patients		
Follow-up Status	Total	With Viral Strains Sequenced	With Viral Sequences Related to That of the Health-Care Worker
Infected before treatment	28	0	...
Established risk factors	62	14	0
Other potential for exposure to HIV	15	13	0
No identified risk	5	3	0
Investigation in progress	3	0	...
Total	**113**	**30**	**0**

*Adapted with permission from Robert LM, Chamberland ME, Cleveland JL, et al: Investigations of patients of health care workers infected with HIV: The Centers for Disease Control and Prevention database. *Ann Intern Med* 1995;122:653-657.

patients with known HIV test results. Furthermore, it is not known how many of the remaining patients underwent invasive procedures and what those procedures were. In most instances, it is not known what stage of infection the health-care workers were in when the procedures were performed (e.g., whether they had AIDS, in which case the titer of HIV in blood would be highest and transmission might be more likely). Nonetheless, the results of these investigations are consistent with previous assessments that the risk of transmission of HIV from a health-care worker to a patient during an invasive procedure is very small.

Patient-to-Patient Transmission

Since HIV is not transmitted by casual contact or fomites, risk of patient-to-patient transmission is very low. There have been reports of patient-to-patient transmission due to reuse of improperly sterilized needles[32] or inadvertent injection of blood or other material from previous patients during nuclear medicine procedures,[33] as well as instances of a presumed breach in infection control in a hospital nursery[34] and in a surgeon's office.[35] In this last-mentioned instance, which occurred in Australia, five of nine patients who underwent minor skin procedures in a surgeon's office on the same day were later found to be HIV-positive. Only one of the five (a man) reported known risk factors. The remaining four were women; three had symptoms consistent with HIV seroconversion in the month after their surgeries. Although the exact mechanism of transmission could not be determined during an investigation conducted 4 years later, a breach of infection control in the office seems likely.

Summary

Concern among surgeons has prompted considerable interest in understanding and preventing the risk of occupationally transmitted HIV infection. Epidemiologic studies and surveillance over the past 10 years have helped to clarify the risk of occupational transmission and to delineate associated risk factors. Health-care workers and patients will be protected best by adherence to infection-control precautions and development of new instruments, equipment, and technology that reduce the likelihood of percutaneous injury to the workers without adversely affecting patient care.

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