A surgeon's risk of AIDS

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A probabilistic model is used to estimate the cumulative risk to surgeons from human immunodeficiency
virus (HIV). Recent data suggest that the probability of infection following percutaneous inoculation is about
1 in 250 cases. Several studies suggest that the frequency of percutaneous injury in surgery is at least 1 in 40
cases, for some as high as 1 in 20 cases. Assuming that on the average a surgeon will perform 350 operations
per year and will practice for 30 years, the cumulative risk of HIV infection will depend on the prevalence of
HIV infection in the surgical population. For HIV prevalences of 1 in 100 to 1 in 10, the cumulative risk per
surgeon ranges from 1 in 100 to 1 in 5, respectively. Based on these risk estimates, it is crucial to decrease the
frequency of percutaneous injury. The case is made for substantial improvements in barrier protection and
modification of surgical technique.

KEY WORDS □9 acquired immunodeficiency syndrome □9 human immunodeficiency virus □9
surgical technique □9 operating room

DURING the 1980's human immunodeficiency vi-
rus type I (HIV or HIV-I) was recognized in
increasing numbers of United States (US) cit-
izens. By April, 1988, the Centers for Disease Control
(CDC) in Atlanta estimated that between 1.0 million
and 1.5 million people are infected with HIV in this
country.4 Among health-care workers in the US and other
countries, acquired immunodeficiency syndrome
(AIDS) "results primarily from HIV infection that oc-
curs outside of the health-care setting."5 Of the AIDS
cases reported in 1988, 5.4% were in health-care work-
ers; at the same time, 5.7% of the US labor pool was
employed in health care.6 However, for certain sub-
groups of physicians, perhaps surgeons, the risks of
infection may be excessive.7 As of March, 1988, the
CDC had identified eight physicians with AIDS, four
of them surgeons, who had no known risk factors for
infection.1 As of June, 1989, the CDC had on record
25 health-care workers worldwide, 18 with documented
and seven with likely HIV "seroconversion" (developing
detectable circulating antibody to HIV) from occu-
pational exposure to HIV.8

With increasing frequency, surgeons are asked to
operate upon known HIV seropositive (antibody posi-
tive, HIV+) patients, and do so unwittingly on undi-
agnosed asymptomatic HIV+ individuals. Because of
this, the HIV epidemic has caused a considerable degree
of concern among the surgical community regarding
their risk of contracting this infection during sur-
gery.16,23,25,43,53

Universal testing of patients for HIV and the poten-
tial restriction of elective surgery for those carrying the
virus have been vigorously called for.16 In light of a
recent Supreme Court decision (107 S Ct. 1123, 1987),
the question of whether it will be legal for a surgeon to
refuse to treat on the basis of HIV status has been
raised.16,44 The environment is therefore ripe for a deep-
ening conflict to evolve between a surgeon's concern
for personal safety and the public's civil rights and
ability to acquire needed medical care.

An assessment of the risk to surgeons and their
operating teams becomes critical at a time when much
of the available data are still sparse and incomplete.
The purpose of the analysis that follows is therefore not
to determine accurately the risk of HIV transmission
to surgeons in the operating room. The goals are two-
fold. The first is to determine if there is reasonable
probability that the risk is high enough to warrant
modification of current surgical practices. The second
is to explore currently available techniques of risk re-
duction in an effort to protect both the surgeon from
infection and the patient from compromise in the qual-
ity of and access to care. If surgical risks can convinc-
ingly be reduced to extremely low levels, the need for
identification of HIV+ patients becomes an irrelevant issue to surgeons and access to care should be universal.

The Model

“Risk” to a surgeon must encompass a career. It must take into account the cumulative exposure to this infective agent over thousands of procedures over many years. The lack of this approach is the most significant shortcoming in many currently available risk estimates. Each surgical career can be viewed as a series of N operations (o): o(1), o(2), ..., o(N).

Surgery, therefore, becomes a sequence of Bernoulli trials if the outcome of each o is 1 of 2 mutually exclusive outcomes: either successful transmission of HIV (t) to the surgeon or unsuccessful transmission (u), such as

\[ u_{(1)}u_{(2)}u_{(3)}u_{(4)}u_{(5)}u_{(6)}u_{(7)}u_{(8)}u_{(9)} \ldots u_{(N)} \]

or

\[ u_{(1)}u_{(2)}u_{(3)}u_{(4)}u_{(5)}u_{(6)}u_{(7)}u_{(8)}u_{(9)} \ldots u_{(N)} \]

et cetera. If the probability of transmission for any given operation is \( p_{(t)} \) and the probability of unsuccessful transmission is \( q_{(u)} = (1 - p_{(t)}) \), then the probability of any given pattern of u’s and t’s can be expressed as a product of p’s and q’s. In general, for r effective transmissions (t) and N-r unsuccessful transmission (u), the probability of the outcome is \( p_{(t)}^{r}q_{(u)}^{N-r} \).

The probability \( p_{(t)} \) of a successful transmission occurring during an operation can be expressed as a product of the probabilities of three independent events: that the patient will be infectious (approximated by the prevalence of HIV+ patients or seroprevalence, s), that the surgeon will be inoculated (injury rate per case, i), and that a given inoculation will be sufficient (efficiency of transmission, e). Therefore, \( p_{(t)} = sie \).

If a surgeon performs c cases per year, and practices for y years, then the total number of cases (N) is \( N = cy \).

Of the \( 2^{N} \) possible outcomes, the only one that is clinically unique is:

\[ u_{(1)}u_{(2)}u_{(3)}u_{(4)}u_{(5)}u_{(6)}u_{(7)}u_{(8)}u_{(9)} \ldots u_{(N)} \]

the outcome where no transmission occurs over a career. The probability of this occurring is \( q_{(u)}^{N} \).

Since the sum of all probabilities of all possible outcomes must equal 1, the cumulative risk or probability of acquiring HIV infection, \( P_{(HIV)} \), is the probability of at least one transmission occurring.\(^{52}\)

\[ P_{(HIV)} = 1 - q_{(u)}^{N} \]

or

\[ P_{(HIV)} = 1 - (1 - p_{(t)})^{N} \]

or

\[ P_{(HIV)} = 1 - (1 - sie)^{y}. \]

It is clear that \( P_{(HIV)} \) will vary substantially between cities and institutions (based on s), between surgical specialties (i), and between individual practitioners (i,c,y). Surgeons have little control (other than restricting or curtailing their practice) over s, c, or y. In 1989, there is no proven way to reduce e. For the practitioner in whom \( P_{(HIV)} \) is significant, the only means of reduction of \( P_{(HIV)} \) is through i: that is, the injury frequency.

Seroprevalence

Most surgeons practice in environments where the HIV infectious rate (“seroprevalence”) of the surgical patients they treat is, and for the foreseeable future will be, unknown. Available data on measured seroprevalence of HIV in US citizens is summarized in Table 1. Perspective is gained by considering that, in the population as a whole, the CDC’s working estimate of 1.0 million to 1.5 million infections in the US implies a 0.4% to 0.6% infection rate, assuming the US Bureau of the Census estimate of 248 million people in 1989 (personal communication, September, 1989).

Several groups listed in Table 1 at low risk for HIV infection have been surveyed. These groups are not representative of the US civilian surgical population. Bear in mind that the self-deferral of subjects at risk for HIV infection and permanent exclusion of known HIV+ individuals in several of these studies (such as the military and blood donors) can significantly underestimate the seroprevalence of the population from which the people were drawn.\(^{9}\)

Data from CDC “sentinel hospitals” (principally from the midwest) suggest that, in patients admitted for reasons not associated with HIV infection, the overall seroprevalence rate is 0.3%. This is about three times the incidence in military recruit applicants from the same cities.\(^{45}\) That the incidence in a hospital population will be significantly larger than in the community as a whole was confirmed in US naval hospitals, where the “point prevalence of HIV seropositivity [0.25%] was more than double the rate in the US Navy in general.”\(^{59}\)
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In a 1-year period ending November 30, 1988, all newborns in New York state (276,609) were tested for HIV antibody. The seroprevalence rate was 0.66% overall. In New York City, the average seroprevalence rate was 1.25%. These figures reflect transferral of maternal antibody to the newborn, indicating maternal infection and perhaps a 40% risk of eventual infection of the newborn.13

In 1987, 5% of all patients (119 of 2302 in a 6-week period) seen at the Johns Hopkins Hospital emergency department in Baltimore were seropositive for HIV. Of the 2275 patients whose HIV status was unknown, 4% (92) were found to be HIV+ by retrospective laboratory analysis. Of patients requiring emergency surgery, 4.6% had unrecognized HIV infection.33 By 1988, the percentage of HIV+ patients in this emergency room had risen to 6%.32

In Washington, DC, the seroprevalence of HIV infection in consecutive hospital admissions of intravenous drug users without AIDS-like conditions was 28%, similar in magnitude to a comparable study in Baltimore.8 It has been recently estimated that between 61,000 and 380,000 intravenous drug users in the US are HIV+, which represents perhaps 5% to 33% of the overall intravenous drug-user population.26 In San Francisco General Hospital, as many as 30% of the patients are at high risk for HIV infection.16 These data suggest that sampling US surgical populations in various locations would reveal HIV seroprevalence rates ranging from 0.1% to 10%.

Related Blood-Borne Retroviral Infections

Human immunodeficiency virus type I may not be the only blood-borne slow retrovirus that is potentially transmissible to surgeons in the operating room. Human t-cell leukemia virus types I and II (HTLV-I and HTLV-II) and HIV type II (HIV-II) have all been identified in the US population. Although HIV-II has clinical effects and modes of transmission similar to HIV-I, it is still of such rarity in the US as to be of no consequence to US surgeons.2

In the US, HTLV-I has been identified mainly in intravenous drug users, with seroprevalence rates of 7% to 49%. In addition, there is an increased incidence of HTLV-I in blacks in the southeastern US of perhaps 2%.7 In certain regions of Japan and the Caribbean HTLV-I is endemic, and there appears to be a lifetime risk of acute t-cell leukemia of 2% to 4% of those infected. The disease associations of HTLV-II are unclear.

Antibody screening methods currently used for HIV infection do not detect HTLV-I infection. A recent study of patients undergoing cardiac surgery and receiving blood screened for HIV antibody demonstrated a 10-fold higher rate of HTLV-I transmission per unit of transfused blood components compared with HIV transmission (0.028% vs. 0.003% per cellular unit).13 The Food and Drug Administration will now recommend screening blood for transfusions for HTLV-I.36 This test will cross-react with the HTLV-II antibody.

It appears that HTLV-I and HTLV-II occur independently of HIV infection. Among 56 intravenous drug users from Queens, New York, 41% were positive for HIV, 18% for HTLV-II, and 9% for HTLV-I.48 The relative seroprevalence of these viruses can vary greatly from community to community (R Gallo, personal communication, August, 1989).

From this information we must presume that, at least in certain parts of the US, the surgical population may have a seroprevalence of HTLV-I and HTLV-II high enough to be of concern to surgeons. It has been suggested that HTLV-I transmission may require inoculation of cellular components of blood (thus it would be less readily transmitted than HIV),13 but nothing factual is known about its transmission risk to healthcare workers. Although the remainder of this analysis will focus on HIV, for the surgeon the entire spectrum of retroviral infections is at issue here.

Incidence of Inoculation

From data on surgical glove punctures and independent data on hepatitis B virus (HBV) infection in surgeons, the risk of significant skin puncture during surgery has been estimated at about one in every 40 cases.25 Further recent data on surgical glove perforation rate (per pair of gloves used) revealed a 48% incidence;5 however, it is likely that this figure is an underestimate since perforations with small (No. 25) needles were probably not all detected. A similar rate of glove perforation was found in another study.34 If the rate of actual skin puncture is an order of magnitude less than the glove puncture rate,23 this implies about a 5% (1 in 20) incidence of percutaneous injury. Correlating well with these figures was a recent survey of accidental percutaneous injuries to general surgeons who performed 2016 operations over a 1-year period: 112 injuries were sustained (5.6%) comprising 107 needlesticks (95.5%), four knife cuts, and one burn.30 Another recent survey found a mean puncture rate of 4.2 per 1000 operating hours, with 25% of surgeons reporting more than nine punctures per 1000 operating hours.37

The incidence of surgical glove tears and skin puncture will of course vary between different surgical subspecialties and between individual practitioners. Surgical specialties handling bone and implanting sharp hardware (orthopedic surgery, for example) will have a higher injury rate than other services such as general surgery. Certain techniques (such as "mass closure")6 within a given specialty may be associated with an unusually high risk of injury.

Risk of Infection Following Inoculation

Only carefully controlled cohort studies can provide an accurate indication of the efficiency of transmission following a given mode of inoculation. In 1988, the CDC Cooperative Surveillance Group detailed one
likely and three documented cases of seroconversion in health-care workers following needlestick or cut with a sharp instrument among 860 workers tested at least 6 months following injury (seroconversion rate of 0.47%). In that study, 103 workers had nonparenteral (mucous membrane or non-intact skin) exposure to HIV-infected blood and none underwent seroconversion. However, the cohort of nonparenterally exposed workers is artificially small because of a 1.5-year lapse in inclusion of this group in the study. Since that publication, the number of seroconversions has not increased, but the pool of exposed subjects has expanded to 1031 (needle sticks or cuts), for a revised percutaneous infection rate of about 0.4% (R Marcus, personal communication, July, 1989).

There are 10 longitudinal studies currently in progress worldwide that are following groups of percutaneously injured health-care workers who meet the following criteria: baseline serum samples were obtained that were seronegative for HIV, their injuries were sustained from patients known to be HIV+, and all were followed for at least 6 months. As of this writing, this group comprises 1625 subjects, of whom six have had documented seroconversions, for a percutaneous infection rate of 0.37% (D Henderson, personal communication, September, 1989).

A separate population of health-care workers has been exposed nonparenterally, and this group is undoubtedly much larger than the percutaneous group. The risk of infection in this group must be very low, as manifested by the several hundred people included in the above studies who have been so exposed and have not undergone seroconversion. Nevertheless, there have been well-documented seroconversions following skin and mucous membrane exposure to HIV-infected blood.

In 1987, the CDC reported three cases of documented seroconversion following nonparenteral exposure to infected blood: on a finger in a person with chapped hands, on the face and in the mouth of an individual with facial acne, and on hands and forearms of an individual with possible contact with an ear affected with dermatitis. These cases were reported outside of the CDC Cooperative Surveillance Group, which has since modified its inclusion criteria to accept health-care workers with nonparenteral exposure of mucous membranes and non-intact skin. In addition, the CDC have emphasized the importance of the need to "minimize the exposure to blood and body fluids of all patients." The apparent ability of HIV transmission to occur through contamination of skin wounds (although not to a health-care worker) was recently well documented.

**Cumulative Risk**

The risk of surgeons acquiring HIV has been typically estimated as low, which is somewhat difficult to quantify. These estimations have been a source of considerable concern, since "... low is a comparative term. The risk is low in comparison with what other risk? One might consider occupational exposure to present a lower risk than some risky sexual behaviors and shared intravenous needle use, but health professionals who do not engage in these behaviors would probably view their occupational risk of infection as comparatively high. We know that approximately one of 250 people percutaneously exposed to HIV will show seroconversion. With the factual data on the risk from nonparenteral exposures so incomplete, the following analysis will focus on percutaneous HIV exposure.

Assume that a surgical population has an HIV seroprevalence of 1/100. At a seroconversion rate of 1/250 and parenteral inoculation rate of 1/40, the risk of transmission per case (p_i) would be 1/1,000,000, given a selection of seroprevalence rates and injury frequencies. Table 2 shows the calculations for the probability of infection, given a selection of seroconversion rates and injury frequencies. In viewing the results in Table 2, realize that the seroprevalence of 1/1000 is less than the average seroprevalence in the US by CDC estimates (4 to 6/1000). If the surgical population's HIV seroprevalence approaches 1/10, as may be realistic for many of our urban centers now or in the near future, the cumulative lifetime risk for a surgeon becomes about 1/10 for an injury rate of 1/40 cases and 1/5 for an injury rate of 1/20 cases. These figures are similar to the cumulative risk estimates of Lowenfels, et al., who predicted an average risk of 1% to 2%; however,

**TABLE 2**

*The probability of contracting human immunodeficiency virus P_{HIV} = 1 - (1 - p_i)^s*, where p_i = i = 0.004, N = s = 350, y = 30, s = seroprevalence, i = injury rate.
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for 15% of the surgeons they surveyed the risk would be 2% to 6%, and for 10% a greater than 6% risk of seroconversion existed.

The issue of what constitutes "excessive risk" has been discussed by Emanuel. He calculated that surgeons operating on emergency room patients in Baltimore (assuming 40 needlesticks per year) could have a 2% annual risk of contracting HIV infection. "The risk taken by surgeons in the emergency department [at Baltimore] is high and probably bordering on the excessive. It can be compared with the risk faced by soldiers at the height of the Vietnam War in 1968 [12,000 (2.4%) of 498,000 died in combat that year] .... It is incumbent on society and the medical profession to reduce the risks to these practitioners."

Ongoing (unpublished) surveillance of over 200 high-risk physicians at San Francisco General Hospital (surgeons, pathologists, and emergency-department personnel) has shown no seroconversions so far (J Gerberding, personal communication, August, 1989). If this is borne out over time and with sufficient numbers of surgeons, it may well reflect a decreased incidence of inoculation among these physicians due to the extraordinary precautions that have become routine on the surgical services at that institution. These precautions will be discussed in detail later.

The above risk estimations do not consider the added risk posed by nonparenteral exposures. Nevertheless, these estimations are high enough to warrant a reevaluation of surgical practices.

Current Precautions

In 1986, a task force at the University of California, San Francisco, evaluated HIV infection control among hospital workers and concluded that "all patients should be presumed to be infected." There was concern that the false security of labeling "known" HIV patients as infected could actually increase unprotected exposure to other infected but unidentified patients. The CDC likewise recommend that "universal" precautions be practiced with blood and body fluids of all hospitalized patients. 12

The level of practicing these "universal" precautions is fair at best in most institutions. These precautions tend to be selectively applied to known HIV+ patients. To make matters more confusing, there is a growing supply of "AIDS equipment" being made available to operating-room personnel (such as face shields and protective gloves) for known HIV+ patients, even though the HIV status of most patients is unknown. This creates a de facto double standard where extraordinary care is practiced for known HIV+ patients in the face of governmental and institutional policy that dictates that such targeted exceptional care is not needed. This was dramatically shown in the study of the Baltimore emergency department where 4% of patients had unrecognized HIV infection: "... there was a substantial potential for [unexpected] exposure to HIV from blood and body fluids of patients with trauma. We are now concerned that the recommended measures are currently being applied inconsistently or selectively to patients whom health-care providers perceive as having a risk of harboring the virus." Following a year of media attention and extensive training of personnel, inadequate precautions were still frequently applied in that emergency department to patients who were not known to have HIV infection: "Overall adherence to universal precautions was adequate 44% of the time, in patients with profuse bleeding it was only 19.5%, ... [and only 16.5% during major interventions]."

The adoption of universal precautions also assumes that the measures now prescribed work well. Among dentists belonging to the American Association of Oral and Maxillofacial Surgeons, seropositivity for HBV was strongly correlated with age and years of practice, but not with use of surgical gloves, masks, or eye shields. It was concluded that gloves may "offer only limited protection against puncture wounds and lacerations." It has been argued that universal precautions have not been evaluated scientifically to see if they are as effective as the more traditional "targeted precautions" for patients with infectious diseases; nevertheless, as the experience in Baltimore points out, selective application of precautions, depending on seroprevalence, leads to a disturbing variant of "Russian roulette" that few would knowingly play.

Strategies For Risk Reduction

If the above analysis of cumulative risk is anywhere near accurate, HIV seroconversion is likely to become a significant risk to surgeons over the coming decades. Immediate attention to methods of risk reduction is warranted. Sim and Dudley stated: "The concept that we must accept risk as part of the medical tradition of putting the patient first is tenable only if that risk is unavoidable. An opportunity for a radical rethink of our [surgical] techniques was missed when the hazards of hepatitis were first recognized ... the appearance of HIV gives a further opportunity to consider change."

Examining the model, P(HIV) = 1 - (1 - sie)cy, there are five variables that can be altered to reduce the risk of HIV infection in a surgeon: seroprevalence, efficiency of transmission, number of cases per year, number of years in practice, and incidence of inoculation.

Sero prevalence

The effect of seroprevalence (s) can be reduced by limiting the surgeon's exposure to HIV-infected patients. This strategy depends on wider testing for HIV. The case for wider testing throughout the population has recently been strongly made. However, more widespread testing of surgical populations can have serious consequences for those who test falsely positive, and for those whose positive test results (true or false) escape the bounds of confidentiality. Furthermore, a
large number of false-positive results may need to be created to protect a surgeon from seroconversion.\textsuperscript{20,25}

False-negative results also must be borne in mind if wider testing is considered for surgical patients. Early in HIV infection (less than 6 to 14 weeks after inoculation), the screening tests currently in use are often not sensitive to the absent or emerging immunoglobulin G response to the viral antigens. In a study of transmission of HIV to recipients of transfused antibody-negative blood products, it was calculated that perhaps 26/one million screened transfusions will be falsely negative for early infection with HIV.\textsuperscript{60}

Of substantial concern is a recent study finding that there may be a significant percentage of false-negative results among high-risk patients: 31 of 133 seronegative homosexual men had HIV isolated from mitogen-stimulated peripheral lymphocytes while they tested seronegative for HIV antibody, and 27 remained seronegative up to 36 months after positive culture.\textsuperscript{31}

Testing of patients is impossible in an emergency, when rapid invasive intervention is required.\textsuperscript{33,30} However, even for nonemergency elective surgical patients, there is still "no evidence [that] supports the contention that knowing a patient is infected with HIV (or, for that matter, any blood-borne disease) will prevent transmission of infection, even in surgical . . . settings."\textsuperscript{20}

Insisting upon universal testing of surgical patients would create significant conflict with those reluctant to undergo testing, and as mentioned earlier, may be challengeable in the courts. If universal patient testing is done, surgeons must decide what to do with positive results; excluding from care what may already be 0.5% of the US population is unethical, so long as the risks are containable.

**Efficiency of Transmission**

There is no current proven way to reduce the efficiency of transmission (e) after inoculation. In 1988, the Burroughs Wellcome Company initiated a randomized study of zidovudine (azidothymidine, AZT) for exposed health-care workers (200 mg orally every 4 hours for six weeks).\textsuperscript{11} There was evidence in laboratory animals that retroviral infection could be prevented with AZT given within hours after inoculation; however, these experiments were performed with murine and feline leukemia viruses, not HIV.\textsuperscript{49,55} After several laboratory workers underwent seroconversion at the National Institutes of Health (NIH), the National Institute of Allergies and Infectious Diseases elected to offer AZT to all health-care or laboratory workers at NIH who have had massive exposures to HIV. With not inconsiderable controversy, this policy-making group viewed the randomized study of AZT for HIV-exposed health-care workers by Burroughs Wellcome Company as unethical.\textsuperscript{4} In the first year of the Burroughs Wellcome study, only 85 exposed health-care workers enrolled, a rate of accrual of subjects far less than that required to provide the thousands of subjects necessary to detect a protective effect. As of June 30, 1989, enrollment in the study was halted, and an "open label" study will be planned (Burroughs Wellcome Company, written communication, July, 1989). These events are unfortunate. Since the toxicity of AZT can be substantial, knowing if the effects of such treatment are worse than the risks of HIV infection following exposure would have been critically important.

**Cases Per Year and Years in Practice**

The number of cases per year (c) and years in practice (y) could, of course, be curtailed in order to reduce a surgeon's risk.

**Incidence of Inoculation**

The only practical strategy for risk reduction is for surgeons to initiate a concentrated effort to reduce the incidence of inoculation (i). With traditional surgical technique, skin and mucous membrane exposure to blood and needlestick puncture has been a customary part of surgical practice. Table 2 suggests that a reduction in inoculation frequencies of from 25- to 50-fold will have to be achieved in order to reduce the risk of transmission below 1/1000 per surgeon.

Two separate approaches to reducing the potential for infection must be taken. First, barrier protection should be improved; precautions in the operating room must provide a different level of protection from precautions in the hospital ward or emergency room. Second, technique changes are needed to decrease the potential for accidents that would violate even stringent barrier precautions. Since barrier precautions would be prohibitively expensive and cumbersome if carried to extremes, a balance between bolstered barrier protection and more careful technique would be practical. This balance will need to be struck by each surgical subspecialty as it critically reevaluates its unique procedures.

**Barrier Precautions**

The areas requiring barriers include the eyes, skin, and air. Eye protection is a necessity for all invasive procedures. In addition to eyeglasses and eyeglass shields, disposable plastic whole-face shields are now available.* Surgical helmets are available in a reusable "space helmet" design with forced air ventilation through a submicron filter.† Perhaps some form of face shield should be used during surgery requiring drilling or heavy irrigating, or where high blood loss is expected.

Improved finger and hand protection is critical. All surgical gloves examined under scanning electron microscopy with freeze fracture techniques had 5-µ channels penetrating the entire thickness of the glove. It was

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* Whole-face shields manufactured by Anago Co., Fort Worth, Texas.
† Surgical helmets, manufactured by Stackhouse Inc., Riverside, California.
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suggested that "double gloving, possibly supplemented by a surfactant/virucide, is a prudent expedient for those handling HIV or HBV virus-infected material." However, there is no evidence that virus-laden fluid (serum) could penetrate these small 5-µ channels effectively; a study of surgical gloves filled with HIV-infected cell suspension and subjected to compression and friction showed no detectable leakage of culturable HIV. Double gloves can also increase the risk of injury by poor fit or by decreasing sensation. One approach suggested to improve sensation is to wear a one-half size larger glove underneath the normal size glove. At the least, double-gloving is prudent for aspects of cases where the risk of glove tears is greatest, such as with bone work or hardware implantation. Perhaps double-gloving should be the standard in the 1990's for all cases where extreme sensitivity is not required.

With regard to needle and knife punctures, it has been suggested that the forces generated during accidents will puncture several layers of latex almost as easily as one layer. In response to this, several attempts have been made to design stronger gloves. Polyethylene gloves have been manufactured that are resistant to knife cuts and injury from sharp bone fragments. Despite recent improvements, it has proven very difficult to make a puncture-resistant polyethylene glove that preserves the surgeon's dexterity and tactile sensitivity (J Lovell, personal communication, July, 1989). Gloves have been manufactured of woven multifilament stainless-steel fibers; this too is a cut-resistant but not puncture-resistant glove. A metal mesh glove has been made of small nickel-plated brass rings about 0.05 in. in diameter. Some work with treating gloves with anti-viral agents has also been done. Unfortunately, there is still "not a puncture-proof glove . . . for people who have to do delicate, tactile-sensitive work."

Our standard operating masks have a poor ability to filter submicron particles and may therefore be inadequate to filter the aerosols created during surgery. Intact papilloma-virus deoxyribonucleic acid (DNA) can be recovered from the vapor of CO₂ laser-treated verrucae. Since papilloma-virus DNA alone has been demonstrated to be infectious, it has been suggested that: "Smoke evacuation is necessary during CO₂ laser therapy. . . . When performing laser therapy with viral infections such as hepatitis or HIV, it would be prudent to assume that the plume of smoke may be infectious." In response to this issue, high filtration "laser masks" are now available; these masks filter particles as small as 0.3 µ. Face-seal leakage, which can substantially reduce the efficiency of a mask, can often be substantially decreased by taping the edges of the mask to the face. Whether such masks would reduce the risk from laser, cautery, or high-speed drill aerosols is unknown.

To protect other skin areas during surgery, double shoe covers and knee-high disposable "boot" covers can be used, with double sleeves for cases where much blood will be encountered. Another technique is to wear knee-high impervious rubber boots. Full head covering that covers all exposed skin is useful; a "legionnaire"-style head cover, originally designed for surgeons operating under ultraviolet lights, may be a practical alternative.

Drying hands and gowning in the middle of operations should not be done by the scrub nurse handing the surgeon contaminated towel, gown, and gloves off the Mayo stand. Unless they are absolutely necessary, glass syringes should be replaced with plastic ones on the Mayo stand. In many cases, sharp bipolar cautery could be replaced by blunt-tipped cautery. Similarly, a new design for a round-ended scalpel blade has been proposed, since most dissection is done with the belly of the scalpel and not with the sharp tip. Nonsterile operating-room equipment should not be handled with contaminated gloves. There is evidence that dried virus remains viable for longer than 7 days at room temperature.

During preoperative shaving of the patient, gloves ought to be worn. Hair clippers, frequently nicking skin, should be decontaminated between patients. Stapling devices may be safer for reapproximating skin than suturing. If this is true, stapling could more often be applied to outpatient and emergency department care as well.

On the orthopedic service at San Francisco General Hospital, broad changes in barrier technique have been instituted by Dr. Lorraine Day. Face shields are routine, and surgical helmets are used for high-risk cases by those who can tolerate them. Respirator masks§ have been used but are reportedly quite uncomfortable to wear for any significant length of time. Laser masks were comfortable but face-seal leakage was a significant concern. Double and occasionally triple layers of latex gloves are worn. Polyethylene cut-resistant gloves were evaluated as a layer between two latex gloves, but they were found generally difficult to use due to reduced sensitivity (they also provided no protection from needlestick). Double shoe covers, double disposable knee-high boot covers, and double sleeves are worn for cases where much blood loss is expected. Plastic cystoscopy aprons are used under gowns for all high-risk patients. Surgeons gown and glove themselves in the middle of

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† Head cover manufactured by Kimberly-Clark, Roswell, Georgia.
‌Head cover manufactured by Kimberly-Clark, Roswell, Georgia.
‌Legionnaire-style head cover manufactured by White Knight Healthcare, Asheville, North Carolina.
‌Respirator masks manufactured by 3M Co., St. Paul, Minnesota.
‌Boot covers manufactured by Kimberly-Clark, Roswell, Georgia.
‌Spectra gloves manufactured by Lovell-Schenck Inc., Charlotte, North Carolina.
‌Laser masks manufactured by Sweet Medical, Lafayette, California.
operations (L Day, personal communication, October, 1989).

Similar precautions have been instituted by Dr. William Schecter on the trauma service at San Francisco General Hospital, including routine double-gloving; for all cases with severe blood loss, impermeable urology aprons underneath the gown and long rubber boots are worn. Such excessive covering can require the use of sweatbands. For work with sharp bone fragments, sterilized golf or gardening gloves have been used between two latex gloves. When deep in the abdominal cavity, surgeons use double sleeves and change them when wet. Bloody gowns are changed when the case permits it, and contaminated skin is cleaned off at those times (W Schecter, personal communication, September, 1989).

As discussed earlier, preliminary data from San Francisco suggest that these surgeons are not contracting HIV infection. It is important to view this forthcoming data from the proper perspective: a lack of seroconversion among them will not have resulted from complacency.

Technique Changes

Unfortunately, "inadvertent skin puncture with a needle or scalpel used on an infected patient is the principal mode by which HIV can be transmitted to a surgeon or nurse in the operating room." Many of these accidents will occur despite extensive barrier precautions, and operative technique must therefore be modified. These techniques will often require refinement of team coordination. "The traditional attitude is that operating is an individual skill . . . there is, however, a choreographic aspect to safe surgical technique . . . ."

Bessinger has analyzed this issue in great detail. In relation to sharp instruments, the scrub nurse can be isolated from the surgeon and assistant. This is a modification of the "dirty field" technique for instruments used in intestinal operations. It is also a "no touch" technique (no two people touch the same sharp instruments at the same time). One option suggested is to use a magnetic pad as a neutral zone for instruments. The magnetized pad keeps instruments from falling and surgeons from quickly reaching for sharp instruments. Verbal warnings are used with instrument placement such as "knife," "needle," or "sharp bipolar." The hands of the person receiving the instrument do not move until the hands of the individual passing the instrument have withdrawn. An alternative (one currently in use on the orthopedic service at San Francisco General Hospital) is to pass all sharp instruments using an emesis basin rather than hand to hand. The instruments are passed with both a verbal command and visual inspection prior to receiving the instrument (L Day, personal communication, October, 1989).

Bessinger suggests that the scrub nurse handle blades and needles only with other instruments; for instance, knife blades are loaded with a needle driver. Loaded needle drivers should be kept with the point down, and needle boards should store used needles. Sharp-pointed instruments should be stored in a remote corner of the Mayo stand. Irrigation sites can be covered with an object such as a plastic Petri dish cover, similar to a technique now used at the University of Cincinnati Medical Center for inspecting vascular anastomoses.

Where possible, tissue should be handled with instruments only and hands kept out of the wound unless necessary. It has been suggested that, during suturing with curved needles, it may at times be safer for an assistant to grasp the point with another needle driver and pull the needle through the tissue.

Microsurgery poses a unique set of problems. Most surgeons need a single thin glove layer for sensitivity here. In addition, many instruments will have to be passed hand to hand during these operations. Fortunately, the operation segments performed under the microscope are not typically the portions most likely to result in HIV inoculation. More adequate precautions can be used during operative opening and closure.

For known HIV+ patients, Bessinger further suggests that decreasing the number of personnel in the operating room will decrease the number of opportunities for exposure. For these cases, only volunteers should scrub; there is no room for angry or anxious assistants. In addition, only upper-level personnel should perform surgery on the known infected patient, without junior-level residents or inexperienced scrub nurses participating.

Conclusions

As the above analysis suggests, surgeons must radically change their practices if the cumulative risks of occupational transmission of HIV are to be reduced to negligible levels. Conflicts between surgeons and their patients can be avoided if effective, reliable protection is universally available to surgeons for all cases. Although some of the barrier precautions described above might be found to be excessive once more is understood about transmission of retroviruses to surgeons, given our current state of knowledge protection must appear excessive to be convincing. A substantial amount of research and development into designing safer yet practical operating-room equipment and clothing is obviously required. Extensive reevaluation of our operative techniques must also be done.

Despite the arguments to limit testing, it goes without saying that this entire discussion about "surgical risks" is based on inadequate data. Accurate data about modes of transmission from patient to surgeon in the operating room would require detailed testing of patients and surgeons. More extensive testing would also be required to determine if HIV+ surgeons pose a significant risk to patients. If effective treatments (such as AZT) are found to reduce the chance of infection following inoculation, they may require rapid knowledge (hours) of the need for administration, perhaps requiring pre-
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operative testing. Surgeons (as the rest of our society) need a confidential system that will permit them to test themselves periodically without detriment, and long-term formal studies of surgeons should be initiated.

Zuger and Miles had carefully examined the traditional medical ethics of western medicine and how it impacts on the AIDS epidemic. They express concern that, with the medical needs of HIV-infected persons about to seriously strain America’s health-care system and with all physicians encountering these patients in the course of a day’s work, “the traditional American medical ethic emphasizing the rights of physicians to refuse to treat these patients seems to us particularly inadequate and incomplete.” They advocate a “virtue-based medical ethic” in which physicians would “commit themselves to obligations beyond those narrowly required by law or contract. It would remind us that medicine is an inherently moral enterprise the success and failure of which depends to a great extent on the integrity of individual professionals.”

These alternative ethics, idealistic and appealing, will need to rest on a foundation of protection for surgeons that convincingly protects them from acquiring HIV. If we could write the medical history of the last decade of the 20th century, we would want to remember that surgeons treated patients regardless of HIV infection and that, through proper precautions, with only great rarity did they contract this infection from surgery. Achieving these dual goals of protecting the surgeon and ready access to care by the HIV-infected individual will require considerable diligence on the part of US surgeons.

Addendum

A recent article by Gerberding et al. (Gerberding JL, Littell C, Tarkin-tong A, et al: Risk of exposure of surgical personnel to patients’ blood surgery at San Francisco General Hospital. N Engl J Med 322:1788–1793, 1990) demonstrated that the current rate of parenteral and cutaneous intraoperative blood exposure at San Francisco General Hospital is 6.4% of cases, with parenteral exposure alone in 1.7% of cases and 5.6 per 1000 operating hours. Although the surgical personnel at this hospital are practicing a high level of infection control, the calculated risk of infection still “represents a major life-threatening occupational hazard.” This study substantiated that double-gloving during surgical procedures significantly reduces the number of cutaneous exposures and should be routine. The study demonstrated that both eyeglasses and goggles are less effective than face shields in preventing facial exposure. In addition, the authors stated that “Neither knowledge of HIV infection nor high-risk status influenced the rate of exposure.”

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