Multicenter Study of Contaminated Percutaneous Injuries in Anesthesia Personnel


Background: Anesthesia personnel are at risk for occupational infection with bloodborne pathogens from contaminated percutaneous injuries (CPIs). Additional information is needed to formulate methods to reduce risk.

Methods: The authors analyzed CPIs collected during a 2-yr period at 11 hospitals, assessed CPI underreporting, and estimated risks of infection with human immunodeficiency virus and hepatitis C virus.

Results: Data regarding 138 CPIs were collected: 71% were associated with blood-contaminated hollow-bore needles, 7% were potentially preventable, 30% were considered high-risk injuries from devices used for intravascular catheter insertion or obtaining blood, and 45% were reported to hospital health services. Corrected for injury underreporting, the CPI rate was 0.27 CPIs per yr per person; per full-time equivalent worker, there were 0.42 CPIs/yr. The estimated average 30-yr risks of human immunodeficiency virus or hepatitis C virus infection per full-time equivalent are 0.049% and 0.45%, respectively. Projecting these findings to all anesthesia personnel in the United States, the authors estimate that there will be 17 human immunodeficiency virus infections and 155 hepatitis C virus infections in 30 yr.

Conclusions: Performance of anesthesiology tasks is associated with

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Contaminated Percutaneous Injuries in Anesthesia Personnel

CPIs from blood-contaminated hollow-bore needles. Thirty percent of all CPIs would have been high-risk for bloodborne pathogen transmission if the source patients were infected. Most CPIs were potentially preventable, and fewer than half were reported to hospital health services. The results identify devices and mechanisms responsible for CPIs, provide estimates of risk levels, and permit formulation of strategies to reduce risks. (Key words: Needlestick; occupational exposure; sharp device.)

The risk of occupational infection with bloodborne pathogens depends on (1) the number and type of exposures to patients' blood or body fluids, (2) the prevalence of infected patients in the healthcare worker's practice, and (3) the risk of infection transmission after a pathogen-contaminated exposure. The most efficient route for occupational transmission of human immunodeficiency virus (HIV), hepatitis B virus, and hepatitis C virus (HCV) is through a blood-contaminated percutaneous injury. Although previous studies reported percutaneous injury rates, device-specific risks, and occupational risks of bloodborne infections, most of the healthcare workers were not anesthesia personnel. Studies of injuries in anesthesia personnel were based on limited data; consequently, the accuracy of derived contaminated percutaneous injury (CPI) rates and infection risks is limited, and the ability to formulate specifically targeted prevention strategies for anesthesia practices is restricted.

The current report is a multicenter study of occupational CPIs in anesthesia personnel. We investigated the devices and mechanisms responsible for CPIs, assessed CPI reporting rates, and calculated CPI rates with corrections to compensate for injury underreporting. In addition, we determined the fraction of CPIs that were potentially preventable and estimated the 1-yr and 30-yr risks of occupational infection with HIV or HCV. These data permit formulation of CPI prevention strategies appropriate for the practice of anesthesia.

**Methods**

Data from anesthesia personnel (attending anesthesiologists [attending], anesthesia residents [residents], certified registered nurse anesthetists [CRNAs], and student registered nurse anesthetists [SRNAs]) who experienced CPIs were collected prospectively from Injury Report Forms from mid-1993 (beginning times varied among the hospitals) through July 31, 1995 at 11 university-affiliated hospitals. Data from anesthesia assistants and student trainees at one hospital were included with CRNA and SRNA data, respectively.

The study protocol was approved by each hospital's human investigation committee. At the beginning of and periodically throughout the investigation, anesthesia personnel were informed about the purpose and design of the study. Personnel with percutaneous injuries were advised to follow their institution's policy on occupational exposures. After initial management of the injury, personnel, who agreed to participate, anonymously completed a prospective Injury Report Form. Because these forms were available in several hospital locations, we compared completed forms to avoid duplicates. Injury Report Forms were included in our study if the device causing injury was contaminated with a patient's blood, other body fluid, or an unknown type of contaminant. To permit confidentiality, we did not investigate the serologic status of source patients and injured personnel. Each hospital's designated study investigator provided additional information about the number of personnel, anesthesiologists, and devices used during the study. Data and calculations for all hospitals are reported in aggregate form.

A retrospective reporting-rate survey was distributed anonymously to all anesthesia personnel in June 1995 to determine the number of CPIs experienced in the previous 12 months, the proportion of injuries reported to hospital health services, and the average number of hours per week spent in patient-care activities. These data were used to determine the hospital health service reporting rate and the Injury Report Form reporting rate (see appendix 1). Contaminated percutaneous injury rates from prospectively obtained Injury Report Form data were corrected to compensate for injury underreporting, where the corrected CPI rate = [uncorrected CPI rate]/[Injury Report Form reporting rate (%)/100].

An injury that transfers a larger volume of infected blood, blood with a higher viral titer, or both, results in a larger viral inoculum and an increased risk of bloodborne pathogen transmission. In our analysis of data from the prospective Injury Report Form, an injury was classified as high risk if, based on the purpose of the device, it was likely to have resulted in a larger volume of blood inoculum compared with other types of injuries. Thus, a high-risk CPI was defined as a CPI from a blood-contaminated hollow-bore needle where it was likely that the needle lumen was filled with undiluted blood (i.e., intravascular catheter insertion or obtaining patient blood).

The mathematical model used to estimate 1-yr and 30-yr occupational HIV or HCV infection risks is presented in appendix 2. Our calculations used HIV and HCV seroprevalence rates representative of a wide range...
of patient populations and assume that HIV and HCV seroprevalences in the patient populations do not change in 30 yr. These calculations also used corrected CPI rates from the current survey and seroconversion rates of 0.003 HIV infections per HIV-infected CPI and 0.02 HCV infections per HCV-infected CPI.

Necessary sharp devices are used to pierce skin or tissue or for cutting. In contrast, sharp devices not used for these purposes or glass items with nonbreakable alternatives are unnecessary (e.g., standard hypodermic needles used for intravenous tubing access and glass capillary tubes) because safety devices and nonbreakable plastic items are available. By assuming that the only time the sharp part of any device must be exposed is during the use of a necessary device, the number of potentially preventable contaminated percutaneous injuries (PPCPIs) equals (1) CPIs from necessary sharp devices occurring between uses, after use, or related to disposal, but not occurring during use of the devices, plus (2) all CPIs from unnecessary sharp devices, where PPCPIs (%) = (PPCPIs × 100)/(all CPIs).

Statistical Analysis

Epi Info Version 6 (USD, Stone Mountain, GA) and SAS releases 6.11 and 6.12 (SAS Institute, Cary, NC) were used for data entry and analysis.

Device-specific injury rates (CPIs/100,000 devices used and 95% confidence intervals, corrected for injury under-reporting) were calculated for needle devices. The number of CPIs from each hospital was considered to follow a Poisson distribution, so the sum of CPIs from the 11 hospitals is a Poisson count. Because the number of CPIs was small, a 95% confidence interval for each type of needle device was calculated for the Poisson mean for the sum using an exact method. Finally, to correct for injury under-reporting, the end points of the 95% confidence intervals were divided by the Injury Report Form reporting rate for all personnel combined (%)/100, and then standardized per 100,000 devices used.

Generalized linear modeling was used for statistical comparison of corrected CPI rates for the four personnel groups. We assumed that the counts followed Poisson distributions because CPIs are statistically rare, but the frequency of occasions when they might occur (use of a sharp device) is high. First, the model assessed for differences of corrected CPI rates among personnel groups without controlling for the effect of different hospitals. Then the data were reanalyzed for differences of corrected CPI rates among personnel groups with the model controlling for hospital as a confounding variable.

### Table 1. Contaminated Percutaneous Injuries in Anesthesia Personnel Groups

<table>
<thead>
<tr>
<th>Anesthesia Personnel Group</th>
<th>Group</th>
<th>Personnel* (n)</th>
<th>FTE (n)</th>
<th>All CPIs [n (%)]</th>
<th>High-risk CPIs [n (%)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residents</td>
<td>372</td>
<td>231.8</td>
<td>73 (53)</td>
<td>18 (43)</td>
<td></td>
</tr>
<tr>
<td>Attendings</td>
<td>311</td>
<td>189.1</td>
<td>37 (27)</td>
<td>12 (29)</td>
<td></td>
</tr>
<tr>
<td>CRNAs</td>
<td>198</td>
<td>129.6</td>
<td>19 (14)</td>
<td>8 (19)</td>
<td></td>
</tr>
<tr>
<td>SRNAs</td>
<td>91</td>
<td>50.5</td>
<td>9 (7)</td>
<td>4 (10)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>972</td>
<td>601.0</td>
<td>138 (100)</td>
<td>42 (100)</td>
<td></td>
</tr>
</tbody>
</table>

FTE = full-time equivalents; CPIs = contaminated percutaneous injuries; CRNAs = certified registered nurse anesthetists; SRNAs = student registered nurse anesthetists.

* All full-time and part-time anesthesia personnel.

A significance level of 0.0083 (α = 0.05/6) was used to account for multiple comparisons.

### Results

**All Contaminated Percutaneous Injuries**

A total of 138 CPIs were reported in prospectively obtained Injury Report Forms; 125 CPIs were associated with 361,943 anesthetics (903,661 h of anesthesia) and 13 CPIs were associated with an unknown number of nonanesthetic procedures (table 1). Seventy-three percent of CPIs occurred in the operating room, 9% occurred in the preoperative holding area, 5% occurred in the postanesthesia care unit or a procedure room, and 13% occurred in other areas. The source patient was known for 98% of CPIs, and the injured person was the original user of the sharp device for 82%.

Hollow-bore needles caused most injuries, and blood was the predominant contaminant (table 2). Devices that caused CPIs were needles on syringes (41%), intravenous catheter styles (20%), suture needles (19%), unattached hollow-bore needles (9%), regional anesthesia needles (4%), scalp blade (3%), and others (4%). The purpose of the sharp device was for intravascular catheter insertion (28%); injection of intradermal local anesthesia (21%); suturing (19%); cutting (9%); intravenous tubing access (7%); administration of spinal, epidural, or caudal anesthesia (5%); peripheral nerve block (4%); obtaining blood (4%); intramuscular or subcutaneous injection (2%); and others (2%). Injuries occurred during use of the device (28%), between steps of a multistep procedure (23%), during or after needle recap (14%), after the device was used but before disposal (25%), or during disposal (9%). The degree of injury was...
Table 2. Devices Causing Contaminated Percutaneous Injuries* and Type of Contaminant†

<table>
<thead>
<tr>
<th>Type of Device</th>
<th>CPIs from Device [n (%)]</th>
<th>Blood-contaminated CPIs from Device [n (%)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle devices</td>
<td>131 (95)</td>
<td>128 (97)</td>
</tr>
<tr>
<td>Hollow-bore needles</td>
<td>104 (75)</td>
<td>102 (77)</td>
</tr>
<tr>
<td>Solid needles</td>
<td>26 (19)</td>
<td>26 (20)</td>
</tr>
<tr>
<td>Unknown type of needle</td>
<td>1 (0.7)</td>
<td>—</td>
</tr>
<tr>
<td>Nonneedle devices‡</td>
<td>7 (5)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Total</td>
<td>138</td>
<td>132</td>
</tr>
</tbody>
</table>

CPIs = contaminated percutaneous injuries.
* No CPIs were caused by safety devices.
† A total of 132/138 (96%) CPIs: blood-contaminated devices; 6/138 (4%) CPIs: 1, cerebrospinal fluid (spinal needle); 1, saliva on scissors (potential for blood59); 1, needle for intravenous tubing injection (potential for blood59); 3, unknown type of contaminant.
‡ A total of 4 scalpel blades (blood-contaminated); 3, others.

Superficial (little or no bleeding) in 26% (36 of 138) of CPIs, moderate (some bleeding) in 67% (93 of 138), and severe (deep injury with profuse bleeding) in 7% (9 of 138). Seventy-four percent (102 of 138) of CPIs were considered to be potentially preventable. Data regarding CPIs from needle devices, the number of devices used, and device-specific injury rates are presented in table 3.

High-risk Contaminated Percutaneous Injuries

Thirty percent (42 of 138) of CPIs were from blood-contaminated hollow-bore needles used for intravascular catheter insertion (38 of 138) or obtaining blood (4 of 138) and were presumed to be blood filled. Therefore, if the source patients were infected, these CPIs would have been high-risk for transmission of bloodborne pathogens (table 1). The devices included intravenous catheter stylets (60%, 25 of 42), needles on disposable syringes (36%, 15 of 42), and unattached hollow-bore needles (5%, 2 of 42). Fourteen percent (6 of 42) of injuries were superficial, 74% (31 of 42) were moderate, and 12% (5 of 42) were severe. Twenty-six of 31 moderate and all 5 severe injuries were associated with medium-to-large-bore needles (22 to 14 gauge). Seventy-nine percent (33 of 42) of high-risk CPIs would have been potentially preventable if safety devices had been used.

Injury Reporting Rates

Retrospective reporting-rate surveys were returned by 500 personnel and indicated that 179 CPIs occurred in the previous 12 months. Survey respondents who incurred four CPIs did not answer the question regarding hours worked per week in patient care (used for deriving full-time equivalent [FTE] data). Therefore, for survey data, there were 0.58 CPIs per yr per FTE (i.e., 175 CPIs per yr per 458.6 FTEs; see table 5). The respondents indicated that they reported 45% (81 of 179) of CPIs to the hospital health services for injury management.

During the 12 months assessed in the retrospective Reporting Rate Survey, personnel returned 59 prospective Injury Report Forms. Therefore, for this period, the Injury Report Form CPI rate, not corrected for underreporting, was 0.098 CPIs per yr per FTE (i.e., 59 CPIs per yr per 601 FTEs; using 601 FTEs from table 1). Using CPIs per yr per FTE rates derived from both data collection instruments, our estimate of the prospective Injury Report Form reporting rate for all personnel combined (the percentage of all CPIs incurred for which prospective Injury Report Forms were returned) was 26% [(0.098/0.38)×100] (see appendix 1). The Injury Report Form reporting rates for each personnel group were 29% for residents, 19% for attendings, 23% for CRNAs, and 64% for SRNAs. Reporting Rate Survey data were insufficient to calculate a reporting rate for each hospital for each personnel group. Therefore, in the generalized linear model analysis, CPI rates for each personnel group at each hospital were corrected for underreporting by using the reporting rate for each personnel group for all hospitals combined.

Contaminated Percutaneous Injury Rates

Corrected CPI rates were 0.27 CPIs per yr per person, 0.42 CPIs per yr per FTE, 1.35 CPIs per 1,000 anesthetics, and 0.54 CPIs per 1,000 h of anesthesia. Injury rates for personnel groups are shown in table 4.

Generalized linear model analysis of corrected CPI rates for the four personnel groups showed that CPI rates were partially dependent on the effect of different hospitals. When the variance among hospitals was controlled, there was a greater discrimination of CPI rate differences among personnel groups, with the following results. Relative corrected injury rates per person (CPIs per yr per person) were greatest for residents (arbitrarily set to equal 1.0), followed by attendings (0.83), CRNAs (0.41), and SRNAs (0.16). These rates were significantly different when comparing residents and CRNAs (P = 0.0005), residents and SRNAs (P ≤ 0.0001), and attendings and SRNAs (P ≤ 0.0001; table 4). The difference between rates for attendings and CRNAs approached statistical
Table 3. Contaminated Percutaneous Injuries from Needle Devices, Number of Devices Used, and Device-specific Injury Rates

<table>
<thead>
<tr>
<th>Type of Device</th>
<th>CPIs (n)</th>
<th>Corrected CPIs* (n)</th>
<th>Devices Used (total for entire study period) (n)</th>
<th>Corrected CPIs/100,000 Devices Used* [95% CI]†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle on syringe</td>
<td>55</td>
<td>211.54</td>
<td>1,512,411</td>
<td>13.99 (10.54–18.21)</td>
</tr>
<tr>
<td>Disposable syringe</td>
<td>1</td>
<td>3.85</td>
<td>112,016</td>
<td>3.43 (0.087–19.13)</td>
</tr>
<tr>
<td>Prefilled cartridge</td>
<td>1</td>
<td>3.85</td>
<td>5,251</td>
<td>0.000–219.43</td>
</tr>
<tr>
<td>Arterial blood gas</td>
<td>0</td>
<td>0</td>
<td>79,663</td>
<td>4.83 (0.12–26.90)</td>
</tr>
<tr>
<td>Other type</td>
<td>1</td>
<td>3.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intravascular device</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV catheter</td>
<td>27</td>
<td>103.85</td>
<td>541,395</td>
<td>19.18 (12.64–27.91)</td>
</tr>
<tr>
<td>Winged needle (&quot;butterfly&quot;)</td>
<td>0</td>
<td>0</td>
<td>6,507</td>
<td>0 (0.00–17.70)</td>
</tr>
<tr>
<td>Suture needle</td>
<td>26</td>
<td>100.00</td>
<td>45,393</td>
<td>220.30 (143.91–322.79)</td>
</tr>
<tr>
<td>Unattached hollow-bore needle</td>
<td>13</td>
<td>50.00</td>
<td>2,391,430</td>
<td>2.09 (1.11–3.58)</td>
</tr>
<tr>
<td>Nerve block needle</td>
<td>4</td>
<td>15.38</td>
<td>8,206</td>
<td>187.46 (51.08–480.02)</td>
</tr>
<tr>
<td>Epidural needle</td>
<td>1</td>
<td>3.85</td>
<td>48,610</td>
<td>7.91 (0.20–44.08)</td>
</tr>
<tr>
<td>Spinal needle</td>
<td>1</td>
<td>3.85</td>
<td>38,129</td>
<td>10.09 (0.26–56.09)</td>
</tr>
<tr>
<td>IV infusion connection needle</td>
<td>1</td>
<td>3.85</td>
<td>13,608</td>
<td>28.26 (0.72–157.48)</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td></td>
<td>17,095</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>131</td>
<td>503.87</td>
<td>4,819,714‡</td>
<td></td>
</tr>
</tbody>
</table>

CPIs = contaminated percutaneous injuries; IV = intravenous.
* Corrected for CPI underreporting.
† The 95% confidence interval for mean corrected CPIs/100,000 devices.
‡ A total of 2,380,130 devices/yr. The number of devices used does not include any safety devices.

significance (P = 0.0141). Relative corrected injury rates per FTE (CPIs per yr per FTE) were greatest for residents (arbitrarily set to equal 1.0), followed by attendings (0.67), CRNAs (0.23), and SRNAs (0.08). These rates were significantly different when comparing residents and CRNAs (P ≤ 0.0001), residents and SRNAs (P ≤ 0.0001), attendings and CRNAs (P = 0.0002), and attendings and SRNAs (P ≤ 0.0001; table 4).

Estimated 1-yr and 30-yr Risks of HIV or HCV Infection from Percutaneous Injuries
For patient populations with low (0.1%), average (1.3%), and high (25%) seroprevalence of HIV infection, the estimated 1-yr risks of HIV infection per FTE are 0.00015%, 0.0016%, and 0.032%, respectively, and the 30-yr risks are 0.00088%, 0.0049%, and 0.094%, respectively (fig. 1). For patient populations with low (0.1%), average (1.8%), and high (25%) seroprevalence of HCV infection, the estimated 1-yr risks of HCV infection per FTE are 0.00084%, 0.015%, and 0.21%, respectively, and the 30-yr risks are 0.025%, 0.45%, and 6.12%, respectively (fig. 1). These calculations used 0.42 CPIs per yr per FTE (table 4). When our infection risk model is applied to the 56,208 anesthesia personnel in the United States (using corrected CPIs per yr per person data from table 4), we estimate a rate of 0.56 HIV infections per yr and 5.18

Table 4. Contaminated Percutaneous Injury Rates

<table>
<thead>
<tr>
<th>CPI Rate</th>
<th>All</th>
<th>Residents</th>
<th>Attendings</th>
<th>CRNAs</th>
<th>SRNAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPIs/yr/person</td>
<td>0.070</td>
<td>0.096</td>
<td>0.060</td>
<td>0.048</td>
<td>0.050</td>
</tr>
<tr>
<td>Corrected CPIs/yr/person†</td>
<td>0.27</td>
<td>0.33</td>
<td>0.31</td>
<td>0.21</td>
<td>0.077</td>
</tr>
<tr>
<td>CPIs/yr/FTE</td>
<td>0.11</td>
<td>0.15</td>
<td>0.098</td>
<td>0.073</td>
<td>0.089</td>
</tr>
<tr>
<td>Corrected CPIs/yr/FTE‡</td>
<td>0.42</td>
<td>0.53</td>
<td>0.52</td>
<td>0.32</td>
<td>0.14</td>
</tr>
</tbody>
</table>

CPIs = contaminated percutaneous injuries; FTE = full-time equivalent; CRNAs = certified registered nurse anesthetists; SRNAs = student registered nurse anesthetists.
* Corrected for Injury Report Form reporting rates.
† Residents and CRNAs (P = 0.0005), residents and SRNAs (P ≤ 0.0001), and attendings and CRNAs (P = 0.0002).
‡ Residents and CRNAs (P ≤ 0.0001), attendings and CRNAs (P = 0.0002), and attendings and SRNAs (P ≤ 0.0001).

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HIV or HCV seroprevalence in the Patient Population (%)

Fig. 1. Estimated 1-yr and 30-yr risks of human immunodeficiency virus (HIV) or hepatitis C virus (HCV) infection in a full-time equivalent anesthesia worker as a function of HIV or HCV seroprevalence in the patient population. The calculations for estimated risks assume that (1) 0.42 contaminated percutaneous injuries (CPIs) per yr per full-time equivalent (CPI rate for all personnel combined, corrected for the 26% reporting rate: table 4), (2) 0.003 HIV infections per HCV-infected CPI,6 (3) 0.02 HCV infections per HCV-infected CPI,6,19,30-32 and (4) the HIV or HCV seroprevalence in the patient population does not change in 30 yr. These data are not adjusted for (1) potential decreased CPI rates resulting from increased use of safety devices and other precautions taken, (2) a decreased HIV seroconversion rate from postexposure chemoprophylaxis,6,37-39 or (3) a decreased HCV seroconversion rate if postexposure anti-HCV therapy is developed in the future. The graphs also illustrate several selected points for HIV and HCV seroprevalence rates in representative patient populations (0.1%, 0.5%, 1%, 5%, 10%, and 25%).18,19,28,29 In addition, in the United States, the average HCV seroprevalence rate in the patient population is 1.3%,28 and the average HCV seroprevalence rate for the general population is 1.8% (the average HCV seroprevalence in the patient population is not available; personal oral communication, October 25, 1996, M. Alter, PhD; CDC).

HCV infections per yr, with 17 HIV infections and 155 HCV infections expected in 30 yr.

Use of Safety Devices

At least one type of needleless or shielded needle safety device was being used at nine hospitals during the study. A total of 392,946 safety devices were used per year (362,902 intravenous access devices [e.g., three-way stopcocks, Luer lock valves, recessed needles] at nine hospitals, plus 30,000 intravenous catheters and 24 phlebotomy devices at one of these hospitals and 20 syringes at another). No CPIs involved safety devices.

Discussion

The Centers for Disease Control and Prevention (CDC) have identified significant risk factors for occupationally acquired HIV infections after percutaneous exposure to HIV-infected blood. These include (1) a deep injury, (2) a device visibly contaminated with the source patient’s blood, (3) a procedure involving a needle placed directly in the source patient’s vein or artery, and (4) exposure to a source patient who died of acquired immunodeficiency syndrome within 2 months.6 Although the average risk of HIV infection after all types of reported percutaneous exposures to HIV-infected blood is 0.3%, the risk, although not quantified, exceeds 0.3% for an exposure involving a greater infectious dose resulting from transfer of a larger blood volume, a higher HIV titer in the source patient’s blood, or both.6

Our definition of a high-risk CPI is consistent with one of the four significant risk factors identified by the CDC but did not include all severe CPIs or visibly contaminated devices (not queried on the Injury Report Form). In addition, we did not determine the source patient’s infection status. Therefore, at least four more CPIs would have been high-risk if we had included all severe CPIs and had gathered information to assess for the two other criteria identified by the CDC. Our finding that 30% of all CPIs in anesthesia personnel are high risk is comparable to the 25% rate reported from a nationwide study that included all hospital personnel.19 In contrast, a previous study27 reported that only 0.55% of injuries in nonanesthesia operating room personnel were high risk. Our data emphasize the unique risk profile of anesthesia personnel compared with others working in the operating room.

The Injury Report Form reporting rate permitted correction of CPI rates obtained from prospective data, and thereby provided better estimates of true CPI rates. Reporting rates in other studies of percutaneous injuries range from 3% to 71%.1,19,36 Because nonreporting of injuries is notoriously common, any data analysis that does not consider underreporting would underestimate the true number and rate of injuries and the risk of occupational infection. Because personnel may be more likely to report high-risk or severe injuries, these could be overrepresented in our data, but this source of bias...
was not assessed. Both the Injury Report Forms and the retrospective surveys were anonymous; therefore, follow-up questionnaires could not be used to determine factors associated with the responses. Because only 45% of all CPIs were reported to employee health services, most injured personnel failed to receive proper postexposure treatment. Postexposure administration of hepatitis B immunoglobulin for hepatitis B virus exposure and chemoprophylaxis for HIV exposure have been shown to be effective.\textsuperscript{4,6,37-39} Postexposure chemoprophylaxis for HIV is most likely to be effective when implemented as soon after exposure as possible; therefore, prompt reporting and follow-up of CPIs is essential.\textsuperscript{6,37-39}

Compared with our data, other studies reported injury rates of 4.2 CPIs per 1,000 h in the operating room for surgeons,\textsuperscript{12} 0.95 CPIs per yr per medical student in an emergency medicine clerkship,\textsuperscript{13} 1.87 CPIs per yr per person for residents and medical students during a training year,\textsuperscript{14} and 0.37 CPIs per yr per emergency room worker.\textsuperscript{15} This suggests that the overall CPI rate for anesthesia personnel is not greater than that for other workers. Because we investigated CPIs at university-affiliated hospitals, we do not know whether our findings can be generalized to anesthesia practices in community hospitals.\textsuperscript{19}

The rate of CPIs per yr per FTE was statistically greater for residents or attendings than for CRNAs or SRNAs, with residents having the greatest relative rate. Previous reports documented needlestick injuries in residents in various hospital departments,\textsuperscript{14,16,17,23} but none has compared injury rates of anesthesia residents with the rates of other anesthesia personnel. All personnel performing procedures involving sharp devices require adequate training and supervision so they learn appropriate work practices to minimize injuries.

Several studies assessed HIV infection risks in healthcare personnel, but those results may vary from ours because of differences in one or more of the following variables pertinent to the calculations: method of data collection, verification that each injury was from a contaminated device, personnel category used for denominator data, injury rate used and correction for injury underreporting, infection prevalence rates in the source patient populations, and seroconversion rate used for a pathogen-contaminated exposure. In a previous report,\textsuperscript{22} the estimated 30-yr HIV infection risks in anesthesia personnel, for clinical conditions relevant to our study, were approximately four times greater than our risk estimates, but they used 1.3 injuries per yr per worker and a higher seroconversion rate per HIV-infected CPI (0.42%) than established currently by the CDC (0.3%). Annual risk of HIV infection from percutaneous exposures was 0.027% per person for medical students and residents in all specialties at an academic center (based on 1.87 injuries per yr per person and a 5% prevalence of HIV-positive patients).\textsuperscript{14} In emergency room personnel, the annual HIV infection risk of CPIs ranged from 0.0005% to 0.007% per worker (based on 0.37 injuries per yr per worker and HIV seroprevalence rates in the patient population of 0.47% and 6.7%, respectively).\textsuperscript{15} In our study, the average risk of HIV infection for all anesthesia personnel combined, 0.0016% per yr per FTE worker, is in the range reported for emergency room workers.

Because the use of postexposure chemoprophylaxis reduces the risk of HIV infection after an injury,\textsuperscript{6,37-39} greater use of these regimens should reduce future risk. Because CPI rates have been shown to decrease with the use of safety devices,\textsuperscript{36,40-44} widespread implementation of various safety devices and other precautions should reduce the risk of occupational infections from all bloodborne pathogens. Our study did not consider infection risk from nonpercutaneous exposures, such as blood contact with mucous membranes or nonintact skin. Inclusion of these events would increase the estimated number of infections. The risk of hepatitis B virus in unvaccinated anesthesia personnel has been well documented, and the hepatitis B vaccine has been shown to be safe and effective and is recommended for anesthesia personnel.\textsuperscript{1,4,18,45} Several recent surveys indicate that approximately 78% of anesthesiologists have been vaccinated against hepatitis B virus,\textsuperscript{23,24} and we expect that the proportion of unvaccinated anesthesia personnel will continue to decrease. No vaccine or postexposure prophylaxis are available to prevent HCV infection.\textsuperscript{30}

Although recapping injuries in nonanesthesia personnel have decreased from 33% in 1986\textsuperscript{4} to 4% in 1994-95,\textsuperscript{41} we found that 14% of CPIs were related to recapping. Although our Injury Report Form did not query for this information, many of these injuries probably were attributable to two-handed recapping. When recapping is necessary, a one-hand technique or use of a mechanical device is recommended.\textsuperscript{36}

Injuries from contaminated solid suture needles may be associated with a lower rate of disease transmission than hollow-bore needles, but our data indicate that they represent a significant proportion of CPIs in anesthesia personnel. Although the injury rate for straight suture needles is more than seven times the rate associated with conventional instrument-held curved suture needles,\textsuperscript{47} intravascular cannulation kits commonly contain
hand-held straight suture needles. If a straight suture needle must be used, when the needle is passed through tissue, it should not be directed toward the nondominant hand, and it should not be held while the suture is being tied. Needleless adhesive skin attachment devices may be appropriate alternatives for securing some types of intravascular catheters.

The rate of injuries from sharp devices and the associated risk of exposure to bloodborne pathogens can be reduced by use of safety devices, including needleless or shielded needle devices, by better product design, by restricting sharp device use to situations in which no alternative exists, by developing safer methods for procedures involving sharp devices, and by use of standard precautions. Many safety devices that have shown effectiveness are marketed, and others are continually being developed and improved. Although safety devices do not exist for use in all types of procedures performed during the practice of anesthesiology, practitioners should evaluate available safety devices as possible replacements for the sharp devices they use that lack safety features.

In conclusion, most CPIS in anesthesia personnel were from blood-contaminated hollow-bore needles. The largest categories of CPIS were related to intravascular catheter insertion, injection of intradermal local anesthetics, and suturing of intravascular catheters. Nearly one third of CPIS were high-risk injuries related to intravascular catheter insertion or obtaining blood. Most CPIS were potentially preventable, and fewer than half were reported to hospital health services for follow-up care. If the risk levels observed in our study remain constant, the estimated average 30-yr risks of HIV or HCV infection from percutaneous injuries for an FTE anesthesia worker are 0.049% and 0.45%, respectively. Risks to anesthesia personnel could be greatly reduced by eliminating the use of unnecessary sharp devices, reducing the use of necessary sharp devices to a minimum, and increasing the use of safety devices, including needleless or shielded needle devices and protective barriers. Anesthesia personnel should follow standard precautions and promptly report percutaneous injuries and other types of blood or body fluid exposures for appropriate postexposure treatment. Future surveillance studies should be directed toward assessing the efficacy of injury prevention devices and strategies.

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Appendix 1: Definitions

Anesthesia Personnel
Anesthesia personnel includes all full-time and part-time personnel involved in patient-care activities with a potential risk for blood or body fluid exposure to contaminated sharp objects (e.g., one full-time person plus one half-time person equals a total of two personnel).

Full-time Equivalents
For Injury Report Form data, the number of FTEs was provided by the study investigators and is the number of anesthesia personnel working on an average weekday in the multicenter study hospitals (e.g., one full-time person plus one half-time person equals 1.5 FTEs). In contrast, the Reporting Rate Survey's FTE count was derived from data regarding hours worked per week in patient-care activities on reported Reporting Rate Survey questionnaires (this also includes any work at night, during weekends, or at hospitals not included in the multicenter study). Because we do not have an exact relation between the study investigators' FTE count and the Reporting Rate Survey's FTE count, we adjusted for the different methods used to obtain FTEs as follows. For Reporting Rate Survey data, we defined one FTE as $\geq 40$ h/week worked, and $< 1$ FTE as $< 40$ h/week worked (e.g., 40 h/week = 1 FTE, 60 h/week = 1 FTE, 20 h/week = 0.5 FTE). These definitions permit a comparison of CPIS per yr per FTE from the Injury Report Forms to CPIS per yr per FTE from the Reporting Rate Survey.

Reporting Rates
Hospital Health Service Reporting Rate. The hospital health service reporting rate was calculated from Reporting Rate Survey data and equals the number of CPIS that survey respondents indicated they reported to hospital health services divided by the total number of CPIS that the respondents indicated they actually sustained in the 1-yr survey period.

Injury Report Form Reporting Rate. Because it was likely that injured personnel would not report all CPIS via prospective Injury Report Forms, the Injury Report Form reporting rate was calculated as follows. For the Reporting Rate Survey respondents, CPIS per yr per FTE equals the sum of CPIS in the survey (CPIS/yr) divided by the number of FTEs (where FTEs equals [the number of survey respondents working $\geq 40$ h/week] plus [the sum of hours worked for respondents working $< 40$ h per week]/40). For the prospectively obtained Injury Report Form data, the number of CPIS (for the same 12-month interval as the Reporting Rate Survey) divided by the number of FTEs equals CPIS per yr per FTE not corrected for underreporting. The ratio of these two CPIS per yr per FTE.
**Table 5. Retrospective Reporting Rate Survey Data**

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Anesthesia Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
</tr>
<tr>
<td>All survey respondents (n = 500)</td>
<td>500/959</td>
</tr>
<tr>
<td>Number of surveys returned/number distributed†</td>
<td>52%</td>
</tr>
<tr>
<td>CPIs/12 mo</td>
<td>179</td>
</tr>
<tr>
<td>CPIs reported to hospital health services</td>
<td>81/179</td>
</tr>
<tr>
<td>45%</td>
<td>46%</td>
</tr>
</tbody>
</table>

Survey respondents who provided hours worked per week data (n = 490‡)
| Mean | 490 | 133 | 190 | 117 | 36 |
| 45.6 | 58.8 | 43.4 | 37.0 | 36.5 |
| Median | 40 | 60 | 40 | 40 | 40 |
| Range | 8–100 | 10–100 | 8–90 | 8–90 | 20–50 |
| FTES (n) | 458.6 | 131.4 | 175.6 | 106.5 | 32.1 |
| CPIs | 175 | 55 | 78 | 35 | 5 |
| CPIs/yr/FTE | 0.38 | 0.42 | 0.44 | 0.33 | 0.16 |

CPIs = contaminated percutaneous injuries; FTES = full-time equivalents; CRNAs = certified registered nurse anesthetists; SRNAs = student registered nurse anesthetists.
† A total of 959 personnel were working when the survey was distributed; 15 survey respondents, accounting for two CPIs, did not indicate personnel category.
‡ A total of 490 of 500 respondents answered the survey question on hours worked per week.
§ A total of 14 survey respondents with hours worked/week data answered did not indicate personnel category.

Appendix 2: Mathematical Model Used to Determine 1-yr and 30-yr Risks of HIV or HCV Infection from Percutaneous Injuries

The probability of an occupationally acquired HIV infection from percutaneous injuries in an FTE anesthesiologist worker in 1 yr, \( P_{HIV/yr} \), is calculated using the formula:

\[
P_{HIV/yr} = (1 - P_{Scrip})^{1 - (1 - P_{Scrip})} \]

where \( P_{Scrip} \) is the probability of seroconversion from one percutaneous exposure to HIV-infected blood, 0.3%, and \( N \) is corrected CPIs per yr per FTE (table 4). Assuming the three determinants of \( P_{HIV/yr} \) remain unchanged over time, the probability of an HIV infection in 30 yr is calculated as:

\[
P_{HIV/30yr} = P_{HIV/yr} = (1 - P_{Scrip})^{30N} \]

Similarly, the calculated 1-yr and 30-yr risks of HCV infection using 2% as the average risk of seroconversion from one percutaneous exposure to HCV-infected blood.

The estimated numbers of occupationally acquired HIV and HCV infections in 1 yr and 30 yr were calculated for the 56,208 anesthesia personnel in the United States. This was based on the number of active members of the American Society of Anesthesiologists: 22,828 attendings and 1,856 residents, and 2,727 recent nurse anesthetist graduates, and 2,051 SRNAs (personal oral communication, June 2, 1997, American Association of Nurse Anesthetists, May 1997 data), and 500 anesthesiology assistants and 70 student anesthesiology assistants (personal communication, National Commission for Certification of Anesthesiology Assistants, July 1997 data). The average HIV seroprevalence in patient populations in the United States (1.3%) was used. The estimated probability of infection per person also differs among personnel groups. For each group, the expected number of HIV infections in 1 yr equals the probability of infection per person times the number of person in the group; the sum of infections for all groups equals the total expected for US anesthesia personnel. Similarly, the estimated number of HIV infections in the United States for a 30 yr period equals the probability of HIV infection per 30 yr person times the number of personnel in each group, summed for all groups (this calculation assumes the same number of personnel in each group during the 30 yr). Data for HCV infections were calculated analogously (with 1% as the average HCV seroprevalence in the US general population [personal oral communication, October 25, 1996, M. Alter, Ph.D., at the CDC]).

**References**


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††† American Society of Anesthesiologists Newsletter. May 1997; 61(S):31

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