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The Risk of Needlestick Injuries and Needlestick-transmitted Diseases in the Practice of Anesthesiology

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ANESTHESIOLOGISTS AS well as other health-care workers (HCWs) are at risk for acquiring blood-borne infections from percutaneous, mucous membrane, or cuta-

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neous contact with blood and body fluids of infected patients.[1-7] The infectious agents of greatest concern in this regard are hepatitis B virus (HBV); human immunodeficiency virus (HIV), the etiologic agent of the acquired immunodeficiency syndrome (AIDS); and hepatitis C virus (HCV), the etiologic agent in the majority of cases of parenterally transmitted non-A, non-B (NANB) hepatitis.[2] Blood is the single most important source for infection by HBV, HCV, and HIV in the occupational setting,[1,6] and a percutaneous injury such as with an accidental needlestick is the most efficient route of transmission.[2,8-14] Less frequent reports in the literature document occupational transmission of other viral, bacterial, parasitic, rickettsial, and fungal agents to HCWs after percutaneous exposures. In total, at least 20 different pathogens have been transmitted through accidental needlestick injuries.[15-20]

This review summarizes existing data on the risk of occupationally acquired blood-borne infections in HCWs concentrating on the specific problem of accidental needlesticks, describes products available for use in the practice of anesthesiology to reduce the incidence of percutaneous injuries, and proposes approaches for modifying procedures and for engineering controls for use in anesthesiology. Although anesthesiologists are at risk for occupational exposure and infection, only a small portion of the relevant studies in the medical literature specifically address anesthesiology. Therefore, much of the information is obtained from studies of non-anesthesia HCWs, but when available, specific data concerning anesthesiologists is noted in this review.

Mechanisms of Transmission and Occupational Risk of Blood-borne Infections

A HCW's rate of exposure to an infectious disease will depend on the prevalence of the infection in the specific patient population and the frequency and nature of the HCW's activities.[1] Although the exact risk of occupational transmission is not known for all blood-borne diseases, multiple factors contributing to the risk have been suggested. These include the HCW's exposure rate, the route

of exposure (percutaneous, mucosal, or intact or non-intact skin), the severity of exposure, the fluid involved in the exposure, the volume of the inoculum and its concentration of microbial agent, microbial pathogenicity and host susceptibility, and for needlesticks, the type of needle (hollow bore *vs.* solid) and the use of gloves.[21-26] The infectivity and concentration of pathogens in the inoculum from the source patient may be affected by the stage of illness, the level of viremia, and any neutralizing effect of antiviral or immunomodulating chemotherapy given to the source patient.[24] Host susceptibility is determined by the individual's immune system status and the presence of protective antibodies. Other factors potentially affecting host susceptibility include hygienic practices and first-aid procedures rendered at the time of the exposure.[24] The risk of transmission also may depend on viral survival, which is related to physical factors in the viral environment (pH, temperature, and humidity) and the time interval between the specimen's withdrawal from the patient and exposure of the HCW.[24]

With this in mind, the overall risk of an occupationally acquired infection for a HCW for a specific period is a function of the number of exposures to potentially contaminated material over the time, the prevalence of carriers of the infectious agent in the patient population, and the rate of successful transmission with a single exposure to contaminated material.[27] The probability that at least one exposed worker will be infected with HIV can be estimated as $1-[(1-P)^n]$ where n is the number of needlesticks and P is the probability of becoming infected with HIV after an injury with an HIV-contaminated needle. Using 0.35% as the HIV transmission rate from a single HIV-infected needlestick and a rate of 1.9 needlestick injuries to a HCW per 1,000 HIV-infected patient days, Wormser *et al.* calculated that, for a period covering 5,000 hospital days for HIV-infected patients (*i.e.,* 10 HIV-infected patients hospitalized for 500 days), there would be 10 needlestick injuries to HCWs and a 3% probability that at least one HCW will seroconvert.[28]

Anesthesiologists have frequent exposure to patient body fluids, usually blood or saliva. Several surveys document the frequency of blood exposures during the practice of anesthesiology. One study reported that contact with body fluids occurred in 36% of commonly performed anesthetic procedures including vessel cannulations, nerve blocks, tracheal intubation or extubation, suctioning the oropharynx or trachea, intramuscular injections, and administration of blood transfusions.[29] Most of these exposures were cutaneous or mucous membrane exposures, but one needlestick was noted in the report covering 863 anesthesia-related tasks. Since saliva and tracheal secretions frequently contained blood, the authors suggested that saliva and tracheal secretions should be considered potentially infective when encountered during anesthetic

procedures. Harrison reported that contamination incidents, including one needlestick, occurred in 14% of 252 anesthetics, with 48 of 75 anesthetists having contact with patient blood.[30] In a report by Popejoy summarizing 684 operations, five anesthesia personnel had blood exposure to mucous membranes or non-intact skin, one suffered a needlestick, and 59 had intact skin exposure.[31] Based upon observations of 206 operations, Panlilio documented 17 episodes of blood exposure to mucous membranes or skin of anesthesia personnel (blood contact occurred in 8.3% of anesthetics), but there were no percutaneous injuries.[32] It is difficult to compare the rate of occupational exposures among reports in the literature because often the denominators for calculation of rates are not given or are not expressed in comparable terms.

Rate of Occupationally Acquired Blood-borne Infections in Health-care Workers

HEPATITIS B VIRUS

Hepatitis B virus is a major cause of acute and chronic hepatitis, cirrhosis, and primary hepatocellular carcinoma. According to estimates made by the Hepatitis Branch of the Centers for Disease Control (CDC) and reported by the Occupational Safety and Health Administration (OSHA), in the United States there are 8,700 HBV infections annually in HCWs who have occupational exposure to blood.‡ Approximately 400–440 of these HCWs require hospitalization, and 200 die from acute or chronic HBV infection. To assess changes in the annual incidence of acute hepatitis B cases in the United States, the CDC conducts surveillance studies and has reported data covering 1981–1988.[33] For this period, there was a decrease in the fraction of new cases of hepatitis B occurring in HCWs. At least two factors appeared to be responsible for the decline: immunization of HCWs with hepatitis B vaccine, which was licensed for use in 1982, and wider use of blood and body fluid precautions recommended by the CDC in 1983[34] and expanded to "universal blood and body fluid precautions" (universal precautions) in 1987.[3]

Seroepidemiologic studies have been conducted in groups of HCWs with frequent blood exposure to determine the prevalence of hepatitis B viral markers as evidence of current or previous infection (table 1). Although the prevalence of serologic markers for past or current HBV infection is 3–5% in otherwise healthy, first-time, volunteer blood donors in the United States,[45] HBV

TABLE 1. Prevalence Studies of Hepatitis B Viral Serologic Markers in Health Care Workers with Frequent Blood Contact

Study (Country)	Year	Participants	Any Marker Positive		HBV Carrier		Total No. of Participants Studied
			n	%	n	%	
Denes[35] (US)	1978	MD	220	18.5	*		1,192
Kunches[36] (US)	1983	EM	16	18.4	1	1.1	87
Berry[37] (US)	1984	A	20	23.3	2	2.3	86
Berry[38] (US)	1984	A	29	18.8	0		154
Fyman[39] (US†)	1984	A	34	48.6	0		70
Berry[40] (US)	1985	A	34	12.7	0		267
Iserson[41] (US)	1985	EMMD	49	15.5	1	0.3	316
Malm[42] (C)	1986	A	10	12.0	0		83
Sinclair[43] (UK)	1987	A	4	3.2	0		125
Vermeulen[44] (SA)	1987	A	17	36.2	1	2.1	47
Total			433	17.8	5	0.4	2,427

HBV = hepatitis B virus; US = United States; MD = physicians; EM = emergency medicine personnel (nonphysicians); A = anesthesia personnel; EMMD = emergency medicine physicians; C = Canada; UK = United Kingdom; SA = South Africa.

* Not studied.

† About 50% of study participants were born outside the United States.

marker seropositivity in anesthesia personnel ranged from 12.7% to 48.6% in several studies conducted in U. S. centers.[35–41] The HBV seroprevalence rate in anesthesiologists can be compared to that found in other medical specialists: 28% in surgeons, 27% in pathologists, 18% in internists, and 4% in the physicians with no patient-care duties, such as research scientists and administrators.[35] In their study of more than 5,500 HCWs in five U. S. hospitals, Hadler et al. determined that the risk of HBV infection was most closely related to the frequency of blood contact, increased with the duration of employment, and correlated with the frequency of accidental needlesticks or puncture wounds.[46]

For HCWs without protective antibodies from previous hepatitis B infection or prior vaccination, 6–30% will be infected after a needlestick exposure from a person positive for HBV surface antigen (HBsAg positive).[1] Carriers who are also seropositive for hepatitis B e antigen (HBeAg) have higher levels of circulating HBV.[47] The risk of HBV infection following a percutaneous exposure to HBeAg-positive blood is estimated to be 27–43%.[12]

HEPATITIS C VIRUS

Recently, the HCV has been identified as the etiologic agent in the majority of cases of sporadic and posttransfusion NANB hepatitis in the United States.[2,48–51] An immunoassay that detects circulating IgG antibodies to HCV (anti-HCV) is being used to better understand the epidemiology of NANB hepatitis.[52] Not all patients with NANB hepatitis test positive for anti-HCV, suggesting either insensitivity of the current anti-HCV assays, the presence of other markers of HCV infection not detected by the currently available anti-HCV assay, or additional viral or nonviral etiologies for the disease.[2,51]

It is estimated there are 150,000–170,000 new HCV infections annually in the United States.[2] Up to 50% of patients develop evidence of chronic liver disease, although the majority of infected individuals may be asymptomatic. High-risk groups for NANB hepatitis include blood or component transfusion recipients, intravenous (iv) drug users, individuals with sexual contact with HCV carriers, and HCWs with frequent blood contact.[2,10,49]

The rate of occupationally acquired NANB hepatitis in HCWs has not been as well quantified as for hepatitis B; nevertheless, its overall incidence and the implications for HCWs can be estimated from existing seroepidemiologic studies and case reports. To assess the prevalence of hepatitis in the United States, the CDC has identified four sentinel counties in which hepatitis transmission patterns reflect nationwide trends. Surveillance in these four sentinel counties over a 7-yr period documented an annual incidence of acute NANB hepatitis of 7.1 cases per 100,000, or about 25% of all cases of viral hepatitis reported.[49] Two percent of the patients with acute NANB hepatitis were HCWs with frequent blood contact.[49] In another study, acute NANB hepatitis was associated with a history of hospital employment in direct patient care or laboratory work in 6.3% of 96 patients.[53] Dienstag reported the average annual rate of acute NANB hepatitis was 0.8% for the staff in 13 hemodialysis units followed over 3 yr.[10,11] There have also been case reports of NANB hepatitis transmitted to HCWs after an accidental needlestick.[8,14]

In a prospective study, four cases of NANB hepatitis were reported in 110 HCWs (3.6%) who incurred witnessed injuries from needles contaminated with anti-HCV positive material.[54] Since only three of the four HCWs demonstrated anti-HCV positivity, the documented HCV

transmission rate was 2.7% (3 cases in 110 anti-HCV positive needlestick exposures).

Epidemiologic and laboratory studies demonstrate that HCV is transmitted by the parenteral route and that HCWs with occupational exposure to blood or bloody body fluids have an increased risk for HCV infection.[2] A survey of HCWs in 13 hemodialysis units indicates that accidental needlesticks were associated with HCV infection.[10,11] There are additional reports of occupationally acquired NANB hepatitis in HCWs, most often after percutaneous inoculation with an instrument or needle contaminated by patient blood.[8-10,13,14] Although many cases of occupationally acquired NANB hepatitis result from overt percutaneous injuries, some HCWs have been infected without identifiable incidents.[10]

HUMAN IMMUNODEFICIENCY VIRUS

The CDC estimates that HIV-1, the viral etiology of most cases of AIDS in North America, has infected more than 1 million persons in the United States.[55] Since the first cases of AIDS were recorded in 1981, more than 202,000 cases have been reported to public health departments in the United States, and of these, more than 65% have died of the disease.[56]

Information on occupationally acquired HIV infection in HCWs is derived from case reports of documented seroconversions, data from HIV seroprevalence studies, and reports of AIDS developing in HCWs with no other identifiable risk factors.[57] General U. S. surveillance data do not indicate an excess of AIDS cases in HCWs because 5% of AIDS patients are HCWs while HCWs constitute 5.7% of the work force. When Beekmann summarized available data on HIV infection in HCWs through May 1990, there were 27 documented occupationally related seroconversions, 9 HIV infections detected in seroprevalence studies, and anecdotal reports of 34 HIV-infected HCWs.[57] In addition, Beekmann noted 66 HCWs with AIDS without identifiable non-occupational risk factors, and 191 HCWs with AIDS whose investigations were incomplete at the time.[57] In 13 HIV-seroprevalence studies conducted between 1985 and 1988, 21 (0.32%) of 6,619 HCWs were found to be HIV positive, with 8 (0.12%) denying community-based risk factors.[57] One case is documented of an anesthesiologist who was infected with HIV as a result of an accidental needlestick occurring during insertion of a central venous catheter in a patient known to be HIV positive.[58]

The three overall factors that determine the HIV infection risk for HCWs in the occupational setting are: 1) frequency of exposure to potentially infected material, 2) prevalence of HIV infection in the patient population, and 3) risk of disease transmission from a single exposure to infected material.[27] It is estimated that 1 million individuals in the United States are infected with HIV (seroprevalence rate of 0.4%). However, the prevalence in patients admitted to hospitals and emergency rooms is likely to be higher. A recent study of 26 hospitals in 21 cities in the United States found the overall rate of HIV seropositivity was 1.3%, ranging from 0.1% to 7.8%.[59] Data from more than 2,300 patients presenting to an innercity emergency department demonstrated that 5.2% were HIV seropositive and that 4.6% of patients admitted directly from the emergency department to the operating room had unrecognized HIV infection.[60]

The risk of acquiring HIV infection is approximately 0.4% for a single percutaneous exposure to blood or bloody body fluid from an HIV-infected patient.[1,7,12] This estimate is derived from data from several large prospective studies. The CDC Cooperative Needlestick Surveillance Group followed 1,201 HCWs who reported blood exposures from HIV-infected patients during 1983–1988.[7] Eighty percent of exposures were from needlesticks, 8% from cuts with sharp objects, 7% from open-wound contamination, and 5% from mucous membrane exposure. There were only four seroconversions, all in HCWs with at least one percutaneous injury from a needlestick. Therefore, the HIV infection risk was 0.46% per percutaneous exposure (4/861) to blood from HIV-infected patients. No seroconversions occurred in HCWs with mucous membrane or non-intact skin exposures to HIV-infected blood or in those exposed to fluids other than blood. Including three other studies of exposed HCWs, there were five seroconversions after 1,242 percutaneous exposures to blood or blood-containing body fluids from HIV-infected patients (0.4% infection risk for each exposure; table 2).[7,24,61,62] The risk of HIV infection after a mucous membrane or cutaneous exposure to HIV-infected blood appears to be less than after a percutaneous exposure such as a needlestick.[63]

Several studies have quantified HIV viral titers in blood or plasma in HIV infection to assess the relation of the stage of infection to potential infectivity. Coombs isolated HIV from peripheral blood mononuclear cells (PBMC) in 97% of antibody-positive HIV-infected patients regardless of the clinical stage of infection.[64] Cell-free virus in the plasma was detected in 23% of asymptomatic patients and in 82% of those with AIDS, with plasma titers of virus correlating with the clinical stage of infection.[64] Plasma titers ranged from 1 to 20,000 viral particles/ml in patients in similar stages of illness.[64] Ho determined that plasma viral levels were about 1 infective dose per 30 μl in asymptomatic HIV-infected patients and increased in symptomatic patients to 3 infective doses per 1 μl.[65] The amount of blood that is likely to be transferred in a needlestick accident in the health-care setting is approximately 1 μl.[65] This data indicated that a larger viral dose would be transmitted after a needlestick injury from

TABLE 2. Major Prospective Studies on Risk of HIV Transmission in Health-care Workers Exposed to Blood
or Body Fluids of HIV-infected Patients

Study (body fluid)	Percutaneous Exposures (needlesticks or cuts)		Mucous Membrane or Nonintact Cutaneous Exposures	
	n	No. of Seroconversions	n	No. of Seroconversions
McEvoy[61] (blood or other body fluids)	76 (blood or other body fluids)	0	74*	0
Gerberding[62] (blood or other body fluids)	129 (blood)	0	213 (blood or other body fluids)	0
Marcus[7] (blood)	861	4†	103	0
Henderson[24] (blood or other body fluids)	176‡	1§	349‖	0
			2,712#	0
Total	1,242	5 (0.4%)	3,451	0

* Also includes five cases of aerosol inhalation.
† All four resulted from needlesticks.
‡ 170 needlestick or other puncture injuries and 6 cuts with a sharp object.
§ Deep cut with blood-contaminated object.

‖ 346 mucous membrane exposures and 3 contaminated open wounds.
Cutaneous exposures to blood (study did not specify whether intact or nonintact skin).

a symptomatic HIV-infected patient than from one who was asymptomatic. High HIV viral titers also were found in plasma (10,000/ml plasma) and in PBMC in the acute phase of primary HIV infection during the "window period," when the patients were seronegative for HIV-antibody.[66] Plasma and PBMC HIV viral titers rapidly declined after the acute phase of infection coincident with the onset of HIV antibody seropositivity.[66]

Use of Needles in the Practice of Anesthesia

Although three factors determine the risk of occupationally acquired blood-borne infections (see above), the frequency of exposure incidents is the only variable that can be effectively altered by HCWs. Therefore, strategies to prevent occupational transmission of blood-borne pathogens have focused on reducing accidental contact with infected material. Since percutaneous injuries such as needlesticks are more effective in transmitting blood-borne pathogens than mucous membrane or cutaneous contact, the prevention of needlesticks and other sharp injuries deserves the greatest attention.

Anesthesiologists use needled devices for withdrawing liquids from containers; administering iv, intramuscular,

or subcutaneous injections; inserting intravascular catheters; collecting blood; and administering regional anesthetics and nerve blocks (table 3). However, needles are specifically needed only for transcutaneous access, injection, or aspiration.[67] When sterile syringes and needles are used to aspirate fluids from sterile vials, ampules, or bags, they pose no infectious risk to the anesthesiologist. Needles and syringes used for percutaneous procedures have contacted blood or body fluids and should be considered capable of transmitting pathogens. Needles and syringes used for injections into iv administration sets can be contaminated by blood despite the presence of check valves in the tubing and without visible back-flow of patient blood.[68] After entry into or connection with a patient's parenteral infusion, the syringe and needle should be considered contaminated.

Risk of Needlesticks

Although several studies have assessed the risk of needlesticks in HCWs, the majority have not specifically addressed the risk for anesthesiologists. Jagger reported on needlestick injuries occurring in a university hospital.[19] The single most frequent cause of needlestick injuries was

TABLE 3. Use of Needles in the Practice of Anesthesiology

Procedures	Needle Contaminated?	Necessary to Use Needle?	Protected or Needleless Device Available?
Aspirate fluids from sterile ampule or rubber stopper vial	No	No	Yes
Inject fluid into intravenous line	Yes	No	Yes
Intramuscular, subcutaneous, or intradermal injection	Yes	Yes	Yes
Insert intravenous catheter	Yes	Yes	Yes
Insert intraarterial or central venous catheter	Yes	Yes	No
Nerve block	Yes	Yes	No
Regional anesthesia (spinal or epidural)	Yes	Yes	No
Direct aspiration of blood or body fluids	Yes	Yes	Limited sizes

recapping a used needle. Thirty-five percent of injuries were from disposable syringes, 26% from iv tubing-needle assemblies, 12% from prefilled cartridge syringes, 7% from winged steel-needle iv sets ("butterflies"), 5% from phlebotomy needles, 2% from iv catheter stylets, and 13% from other devices. The rate of injury (injuries per 100,000 devices purchased) from devices requiring disassembly was as much as 5.3 times the rate for single-use syringes, which could be placed into protected containers without removing or recapping the needle. HCWs indicated that they chose to recap needles as a result of judgments made about competing hazards: the need to carry several uncapped needles to a disposal container at the same time, the need to safely store syringe contents used for multiple doses at different times, the need to protect colleagues from injury before needles were discarded in a container, and the need to protect themselves from an exposed contaminated needle during disassembly of a device. The findings from this study may not be applicable to anesthesiologists because the data were taken from reported needlesticks that mostly involved non-anesthesia nursing personnel.

It is well recognized that a large number of needlesticks, especially those occurring in physicians, are not reported. Hamory used data from a questionnaire to demonstrate that 75% of needlestick injuries in HCWs were not reported to the employee health service.[69] In a survey of house officers, respondents admitted that only 30% of needlestick injuries had been reported at the time of the exposure.[70] Nineteen percent of the interns and residents reported one or more needlestick exposures to HIV-infected blood. Popejoy found that only 8% of percutaneous, mucous membrane, or non-intact skin exposures occurring in operating room personnel and 3% of physician exposures were reported to the employee health department.[31]

Three recent observational studies indicated that surgical and operating room personnel experienced frequent exposure to blood and that the majority of cutaneous or mucous membrane contacts could be prevented by mucocutaneous barrier protection, including gloves.[22,31,32] Percutaneous blood exposure occurred in 1.7–5.6% of surgical procedures, most often involving surgical personnel.[22,31,32,71] Knowledge of a patient's HIV diagnosis or HIV risk status did not reduce exposure rates.[22]

In reports describing anesthetic practices, nine needlesticks (only six were contaminated needles) occurred in 42 anesthetists performing about 7,000 anesthetics during a 3-month period (a needlestick injury frequency of 0.13% per anesthetic).[72] Twenty percent of the anesthetists received a needlestick, yielding a rate of 0.86 needlesticks per person-year. Harrison reported one needlestick during 252 anesthetics, for an incidence of 0.4% per anesthetic.[30] Popejoy noted one anesthesia HCW had a per-

cutaneous exposure (unspecified whether needlestick or cut) in a study of 684 operations, for an incidence of 0.15% per anesthetic.[31] Panlilio reported no percutaneous injuries by anesthesia personnel during 206 operations involving an average of 2.3 anesthesia personnel per operation.[32] Combining the data from these surveys, which comprised 8,142 anesthetics, 11 percutaneous exposures (10 documented to be needlesticks) occurred in anesthesia personnel, for an overall percutaneous exposure incidence of 0.14% per anesthetic.

In a study that examined anesthetic procedures and contact of anesthesia personnel with patient body fluids, Kristensen reported no needlestick injuries in 482 invasive procedures involving needles (278 peripheral venous cannulations, 32 arterial punctures, 128 regional blocks, and others); however, one needlestick occurred with a needle used for injection in an iv port.[29]

Using information from a search of several literature databases, Buergler et al. calculated the occupational risk of HIV infection for anesthesiologists.[73] The probability of an individual becoming infected with HIV in a single year as a result of a needlestick injury was determined by the formula: $P = r \times h \times e$, where r is the risk of infection with each parenteral exposure to HIV-infected blood or body fluids, h is the prevalence of HIV-infected patients in the specific patient population during the year, and e is the number of needlestick injuries for the year. For the calculations, Buergler et al. assumed that an anesthesiologist would incur 1.3 needlestick injuries per year and the seroconversion rate was 0.42% for each parenteral exposure to HIV-infected blood. The calculated 1-yr risk of occupationally related HIV infection for an anesthesiologist ranged from 0.002% to 0.129% when the prevalence of HIV-infected patients in the surgical population varied from 0.32% to 23.6%.[73]

Management of Needlesticks

All health-care institutions should have a detailed protocol for assessment, treatment, and follow-up of HCWs with occupational exposure to blood, tissues, or other body fluids to which universal precautions apply.‡ [63] After initial cleaning of the site, wound care, and first-aid, the HCW should immediately contact the appropriate consultant, who should evaluate the extent of the exposure and the need to determine the HBV, HCV, and HIV serologic status of the source patient, if known, and the HCW.[63,74,75] The OSHA standard requires that, after an exposure incident, the employer 1) document the route and circumstances of the exposure; 2) within applicable laws, when feasible, identify the source individual; and 3) if not known to be HBV or HIV positive, test the source individual for infectivity after obtaining consent.‡ The exposed employee's blood should be collected and tested

for HBV and HIV after consent is obtained.‡ Some injuries may require tetanus prophylaxis.

The CDC has published protocols for treating HCWs who may have been exposed to HBV.[74] These are based on the vaccination and immune status of the exposed HCW and the HBsAg serologic status of the source patient. Unvaccinated individuals and those known to be vaccine nonresponders should receive hepatitis B immunoglobulin.[74] A two-dose regimen of hepatitis B immunoglobulin is about 75% effective in preventing hepatitis B after percutaneous exposure. Hepatitis B vaccine should be offered to unvaccinated HCW after a needlestick injury.

Since the relationship between the clinical course of hepatitis C and the presence or absence of anti-HCV, the antibody detected by the only serologic test for HCV, have yet to be elucidated, there are no specific recommendations on HCV serologic testing after a needlestick injury. The use of immunoglobulin has had equivocal effectiveness as prophylaxis against NANB hepatitis, but the CDC notes that it may be reasonable to administer a dose as soon as possible after NANB hepatitis exposure.[75]

When a HCW has had a percutaneous injury with the source patient being HIV seropositive or suspected to be HIV positive, the circumstances of the exposure should be recorded in the worker's confidential record, and the HIV serologic status of HCW should be determined confidentially.‡ [63] If HIV seronegative, the HCW should be periodically tested for a minimum of 6 months after the exposure. After receiving counselling, the HCW can decide whether to initiate prophylactic zidovudine in an attempt to prevent HIV infection. Although many institutions are offering post-exposure prophylactic zidovudine to HCWs after significant blood exposure, the CDC states that current clinical and laboratory studies are inadequate to document its effectiveness in this situation.[63] Significant side effects are associated with zidovudine, and its long-term toxicity in healthy individuals is unknown.

Universal Precautions

The CDC and OSHA have recommended the use of universal precautions as a strategy for prevention of occupational transmission of blood-borne infections to HCWs.‡ [1] Included among these recommendations is the use of appropriate barriers in situations when the HCW anticipates contact with blood or other body fluids. Although barriers can reduce the risk of cutaneous or mucous membrane exposure to blood and body fluids, items such as gloves or gowns can be easily penetrated by needles and may be ineffective in preventing percutaneous injuries. Therefore, the CDC universal precautions also include specific recommendations to prevent injuries caused by needles and other sharp instruments (table 4).

TABLE 4. Needle Precautions Included in the Centers for Disease Control Universal Precautions[1]

1. Needles (contaminated) should not be recapped, purposely bent or broken by hand, removed from disposable syringes, or otherwise manipulated by hand.*
2. After they are used, disposable syringes and needles and other sharp items should be placed in puncture-resistant containers for disposal; the puncture-resistant containers should be located as close as practical to the use area.
3. Reusable needles should be left on the syringe body and should be placed in a puncture-resistant container for transport to the reprocessing area.

* This recommendation has been modified by the Occupational Safety and Health Administration (see text for details).

When using needles in the practice of anesthesiology, both sterile and contaminated devices must be handled. When medication is aspirated from a sterile vial before administration to a patient, a sterile needle remains sterile, and therefore recapping does not entail infectious risk to the practitioner. Once a needle has been used for injections into iv tubing, it should be treated as contaminated since blood may be present in the administration tubing.[68] Needles used to administer iv infusions such as antibiotics or vasoactive medications should be handled in a similar manner. Needle stylets used for iv or intraarterial catheters, as well as needles and stylets used for nerve blocks or regional anesthetics, should be considered contaminated and disposed of immediately after use or placed back on the sterile procedure tray, from which they can be carefully removed and placed in puncture-resistant containers. If possible, the individual who performed the procedure should be responsible for disposal of the sharp objects since that person would be most familiar with the number and location of the items used.

All HCWs, including anesthesia personnel, are at risk for accidental needlesticks from contaminated devices that do not undergo proper disposal after use. Examples of this include needles left on a patient's bed that may subsequently injure personnel who lift or transport patients, sharp objects in dirty linen containers that may injure laundry workers, and unprotected needles that can puncture plastic trash bags to injure personnel responsible for cleaning or transporting waste materials.[19]

Although use of universal precautions can reduce physicians' exposures to blood,[76] many HCWs are not using these strategies despite intense educational programs.[77-80] HCWs appear to have adequate knowledge of needlestick precautions,[79] but these often go unheeded because individuals are too busy or believe that, in some instances, recapping is less risky than handling an unprotected needle.[77]

Many studies have indicated that accidental needlesticks were frequently the result of needle recapping.[7,19,81-83] Recapping-related attitudes and behaviors were studied

at four teaching hospitals.[77] Despite adoption of universal precautions as the hospital policy, inventories of needle disposal boxes demonstrated that 8–58% of used needles were recapped.[77] Recapping was related to inadequate knowledge, forgetting or being too busy to follow universal precautions, or a belief that recapping protects HCWs and colleagues from needlesticks.[77]

Occupational Safety and Health Administration Standard on Occupational Exposure to Blood-borne Pathogens

After petitioning by several HCWs' unions, OSHA proposed and has now finalized standards to reduce every employee's occupational exposure to blood-borne pathogens.‡ This federal standard requires that employers have an Exposure Control Plan that mandates universal precautions and includes engineering controls (equipment or devices that isolate or remove the hazard of blood-borne pathogens) and work practice controls (practices that reduce the likelihood of exposure by altering how a task is performed) to eliminate or minimize employee exposure. The OSHA standard also requires that employees use appropriate personal protective equipment. Employers must educate and train employees on proper handling of needles and sharp devices. In the explanation of the standard, OSHA points out that engineering and work practice controls are often codependent, because specific work practices may be necessary to ensure effective operation of engineering controls. An example cited is the rigid needle disposal container, which provides no protection if an employee continues to recap needles and discards them in the trash.

Although many of the recommendations from the CDC universal precautions are included in the OSHA standard, it contains specific regulations that go beyond the language used by the CDC. The OSHA document states that "contaminated needles and other contaminated sharps shall not be recapped or removed unless the employer can demonstrate that no alternative is feasible or that such action is required by a specific medical procedure. Such recapping or needle removal must be accomplished through the use of a mechanical device or a one-handed technique."‡ Procedures cited as possibly requiring recapping of contaminated needles include drawing a sample from an artery for blood gas analysis and incremental administration of iv anesthetics.

Strategies for Reducing Accidental Needlestick Injuries

Educational efforts to prevent inappropriate recapping of needles generally have been unsuccessful in eliminating sharp object-related injuries.[80,84] It had been assumed that if HCWs were taught that needles should not be recapped,

there would be a proportional decrease in the frequency of needlestick injuries. However, informational programs and implementation of universal precautions shown to reduce needle recapping did not significantly change the incidence of needlesticks.[80,84] Effective policies to prevent recapping needles have not reduced needlesticks because the risk of injury is a tradeoff between the risk of handling an exposed needle and the risk of recapping. Additionally, only a portion of needlesticks are caused by items that could be resheathed. Several individuals have pointed out that other strategies must be sought.[80,84,85]

Two studies have demonstrated that gloves do not prevent all percutaneous-needle injuries to the hands.[22,25] An in vitro study suggested that, although the blood volume transferred by a needlestick increased with needle size and depth of penetration, it was reduced at least 50% by passage of the needle through a latex or vinyl glove.[26] Double-gloving may provide additional protection against skin puncture by an accidental needlestick. In a study of surgical personnel, Gerberding found that 17% of either the single glove or the outer double glove were perforated after use, whereas only 5.5% of the inner double glove had been violated.[22]

Reducing the hazards from needled devices includes developing alternative methods for performing medical procedures, restricting the use of needles to situations in which no alternative exists, and when needles are required, seeking better product design.[19] These goals have not been achieved for the vast majority of needle use in anesthesia and other health-care areas. However, many new products have become available that permit use of needleless or protected needle devices for many applications (Appendix, table 3). Assessments in non-anesthesia situations indicate a decrease in needlestick injuries after implementation of one of these devices.[86] Modifications of some existing devices are anticipated as new products are developed and tested. Procedures without available safety devices should be the focus of further research and development.

Needled devices are necessary only for transcutaneous procedures, because stopcocks, recessed sheathed needles, and valved ports are available to introduce medications and fluids into iv administration tubing or to sample blood from intravascular catheters. Procedures that require the use of needled devices include: insertion of intraarterial or central venous catheters, nerve blocks, and regional anesthesia. Availability of devices for direct aspiration of blood or body fluids is limited. While needleless devices are also available for aspirating medication from sterile vials or ampules, a sterile needle used for this purpose remains sterile, and therefore, recapping does not present an infectious risk for the practitioner. To ensure maximum safety when needled instruments must be used for any purpose, anesthesiologists must avoid recapping by

the two-handed technique, appropriately use needle and syringe disposal containers, and comply with universal precautions.§·‖ [15,77,87] If it is absolutely essential to recap a needle, use of a one-hand recapping technique prevents the contaminated needle from being directed toward the HCW's unprotected hand. In the one-hand technique, the needle cap is placed on a flat surface and is "scooped" up with the needle attached to the syringe. The cap is then set onto the needle hub by pushing it against a flat surface. With this technique, the HCW is not required to direct the needle toward the non-dominant, unprotected hand. Alternatively, a needle recapping device can be used to hold the cap when reinserting a contaminated needle (Appendix). Caution must be used to ensure the needle does not perforate the cap, as this creates a hazard that may be unrecognized until an injury occurs.

Placing puncture-resistant disposal containers near the work site has reduced some types of needlestick injuries.[80,88] When the containers are not overfilled and are properly closed, this strategy also will prevent the portion of needlestick injuries due to needles that pierce trash or laundry bags. Puncture-resistant sharps disposal containers must be easily accessible in all work locations. By having one container on each portable medication/anesthesia equipment cart, the sharps container can be moved closer to the work area as needed. When a sharps container becomes three-quarters full, it should be sealed and properly discarded to prevent overfilling-related needlestick injuries.

Work practices may be modified to attempt to reduce accidental needlesticks. Skilled practitioners, not trainees, should perform procedures involving needles in uncooperative patients, because patient movement may result in injury to the HCW. Ancillary personnel may be needed to restrain patients during procedures. Additionally, it may be unwise to place procedure trays containing needles and sharp objects directly on the patient. For starting central venous catheters, the anesthesiologist might consider working from a procedure tray placed on a stand directly in front of him/her rather than to the side. This will permit used needles to be returned to the tray within direct vision and without distraction of the anesthesiologist's attention from the procedure being performed. Some practitioners routinely include extra sterile syringe and needle assemblies on procedure trays to eliminate the need to pick up previously used equipment. Procedure trays and component devices should be redesigned to reduce needlestick risk by facilitating handling of needles and other sharp objects. New design features that could

be incorporated into procedure trays include: 1) separation of needled from non-needled devices, 2) orienting needles in the same direction on the tray, 3) extra sterile needles and syringes so that contaminated devices do not need to be reused, 4) safer needled devices and use of protected needle or needleless devices when possible, 5) a mechanism to isolate contaminated needles or sharp objects for later disposal, and 6) a disposable forceps for handling contaminated sharp objects during disposal. Continued research and development of new products is needed to reduce needlestick hazards when needled devices must be used for anesthetic procedures.

Needleless or Protected Needle Devices

RATIONALE AND PRODUCT DESIGN

Based on data covering causes of needlestick injuries to HCWs in a university hospital, Jagger estimates that it is possible to eliminate 90% of accidental needlesticks by improving the design of devices.[19,85] An estimated 800,000 needlesticks occur in hospital HCWs annually, and if approximately 2% of hospitalized patients are HIV positive, then 16,000 needlesticks will occur that could transmit HIV to HCWs.[85] With a seroconversion rate of 0.4% after each HIV-positive needlestick, 64 HCWs will become infected from needlestick injuries. If effective devices can reduce this rate by 90%, then HIV infection can be prevented in 57 HCWs annually.

Numerous factors determine whether a needlestick prevention product will prove applicable and effective for protecting HCWs from injuries (table 5). The product should require minimal or, ideally, no user action to engage the protective mechanism, since additional steps or complicated procedures could make an injury more likely.§ In addition, the product must be convenient to use and compatible with other equipment; otherwise, its application will be limited no matter how sound the technical aspects of its design. Ideally, the protective mechanism should be an integral part of the product design rather than require use of additional devices.§ [19] The use of needlestick prevention products must not introduce other problems such as increase in the risk of nosocomial infections via microbial contamination of open ports, air embolism via a malfunctioning valve or a nonoccluded injection port in an iv manifold,[89,90] or unintentional tubing disconnections. Safety features should be effective both before product disassembly and after disposal.[19]

NEEDLELESS OR PROTECTED NEEDLE PRODUCTS THAT MAY BE SUITABLE FOR USE IN ANESTHESIOLOGY

Many manufacturers have developed protected or needleless products in response to HCWs' concerns re-

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§ ECRI: Needlestick-prevention devices. Health Devices 20:154–180, 1991.

‖ Greene ES: Infection control in anesthesia and critical care medicine. Anesthesiology Report 3:280–290, 1990.

TABLE 5. Desirable Characteristics of Needleless or Protected Needle Products

A. Product design protects health-care worker (HCW) from accidental needlestick
  1. Passive mechanism to protect needle, i.e., use of device should automatically activate mechanism to protect HCW.
  2. Mechanism for using the device does not require HCW's hands to be in front of the needle at any time.
  3. Mechanism that protects needle is permanently locked once procedure is finished to protect personnel if the device is not disposed of properly.
B. Product is convenient to use, functional, and safe
  1. Techniques for use should be similar to nonprotective device facilitating a short learning period and encouraging HCWs to use it.
  2. Components must be compatible with other equipment.
  3. Requires only a few component parts so that it can be easily stocked and supplied.
  4. No risk of contamination of sterile portions of the product during use.
  5. Product is designed so that it can be used for many kinds of procedures, e.g., an intravenous catheter that can also be used for arterial lines and for Seldinger technique for central venous lines; a syringe assembly that is protective when various length needles are used.
  6. When using the device, HCWs should not be exposed to blood or body fluids, e.g., "flashback" of blood when starting intravenous catheter.
  7. No risk of patient complications, e.g., air embolism or unintentional tubing disconnections.
C. Product is cost-effective
  1. Increased cost of product offset by cost of injuries that are prevented.

garding risks of accidental needlesticks (Appendix). Because of the great interest and need in this area, many products are available in the marketplace, but unfortunately, few have had widespread clinical testing for effectiveness.

Several types of iv catheters and needles provide some degree of protection against needlesticks when compared to traditional devices. Needleless or protected needle devices have been developed for incremental administration of bolus doses of medications from a syringe or for infusion of drugs into an iv delivery system. These products are intended to eliminate or protect needles attached to syringes or "piggy back" infusions. Often they require specialized ports that may be incorporated into iv administration tubing and offer an alternative to stopcocks used by many anesthesiologists for this purpose. Some of the devices for delivering infusions consist of a needle recessed in a cylindrical, rigid plastic housing designed to be connected to special rubber septum injection ports in administration sets or "heparin locks." The protective housings of these products often incorporate a mechanism that locks with the injection port of the iv tubing to prevent disconnections at this junction. Since the needle is recessed and shielded in these devices, accidental needlesticks should be prevented.

Several types of multiport manifolds, usually consisting of two or three female Luer injection sites, can be inserted in an iv administration set. These can replace standard stopcocks for use during an iv anesthetic induction, for incremental doses of medications, or for multiple infusions. As with stopcocks or any open port, sterility needs to be maintained by covering the open port with a sterile cap or syringe when not in use. Air entrainment resulting in air embolism has been reported with some of these devices when unused ports have not been covered with an occlusive cap, as recommended by the manufacturer.[89,90] Additionally, instructions for use of these products usually indicate that air needs to be flushed from each port during initial assembly to prevent the iv injection of air. Because of the dead space volume in the ports of some products, they may be inappropriate for use in pediatric patients, when a small volume of drug may be injected.

Unprotected needles attached to syringes are a significant risk to HCWs. This problem has been addressed in several ways so that the contaminated needle is shielded. Additionally, there are devices that hold the needle cap while the HCW uncaps the needle and during recapping of the contaminated needle, thereby eliminating the need for two-handed recapping.

Several manufacturers have developed closed systems that attach to intraarterial or central venous catheters and permit venous or arterial blood access without open stopcocks or needles and without the need to discard blood. The tubing of the devices is connected to an iv or intraarterial catheter at one end and to a transducer system at the other and usually allows for intravascular pressures to be measured between blood sampling. When used as intended, these kinds of systems eliminate the risk of transducer and tubing contamination originating from open stopcocks.

Is There Evidence that Needleless or Protected Needle Devices Work?

Although many products are available and are marketed using testimonial data, there is a paucity of controlled studies in this area. A recent publication indicated that, at the time, there were no data available to indicate whether devices with external sheathing or internal blunting mechanisms are safer than conventional products.[91] Studies are in progress to assess the effectiveness of these devices, as well as several preliminary reports suggesting that implementation of needleless iv systems was temporally associated with a reduction in needlestick injuries.[86,92,93] For the 6 months following the introduction of a needleless iv administration system for use in a university hospital, there was an overall reduction of

51.9% in reported sharp-object injuries.[86] Needle-related injuries decreased by 43%, iv-related injuries by 88%, and trash-related injuries by 85.7%.

Some products advertised as needlestick prevention devices may offer little or no actual protection for the user. One study found that a 1–2-cm-diameter funnel-shaped shield on the needle cap reduced the number of "misses" in a trial using the two-handed recapping technique.[94] However, it is possible that if employment of this device results in increased use of the two-handed recapping technique for contaminated needles, the number of needlesticks from recapping accidents might increase.

Before selecting specific needlestick prevention devices, hospitals should conduct clinical trials that include the participation of HCWs who will eventually use the products. The number of needlestick prevention devices used in a hospital should be minimized to ensure the HCWs are familiar with the products and their proper use.§ Noncompliance by HCWs who choose not to use the needleless or protected needle devices also will limit product effectiveness.[81]

Are Needleless or Protected Needle Devices Cost Effective?

Needleless or protected needle devices generally cost more per item than the conventional devices they replace. To determine whether a needleless or protected needle device is cost effective, several expenses (e.g., treatment and prophylaxis for the injured HCW and employee health personnel time) need to be considered. When a needlestick injury occurs, the HCW must receive counseling on the risk associated with the exposure, and options for treatment must be explained.‡ Both the HCW and the source patient may need to be screened for serologic markers of HBV, HIV, and possibly HCV and for liver function tests. Based on the HCW's HBV vaccination and immune status, hepatitis B vaccine or hepatitis B immunoglobulin may be indicated. Immunoglobulin may be administered when hepatitis C is likely in the source patient. Some institutions offer prophylactic zidovudine after exposure to known HIV-positive or highly suspected unknown HIV-infective material. Finally, the cost of the time lost from work for the HCW and the expenses for employee health personnel salaries and record keeping must be included. In one university hospital, the direct annual cost of treatment for sharp-object injuries (adjusted for inflation) increased seven times during the 14-yr period from 1974 to 1988.[82] Although the cost per injury increased only 30%, there was an increase in the number of reported injuries and more uniform postexposure treatment at the institution.

In Gartner's institution, implementation of a needleless iv system was associated with a 16% increase in product

cost for a 6-month period.[86] A portion of the increased cost was offset by the overall reduction in expenditures for treatment of HCWs incurring needlestick injuries. Additional savings resulted from alteration of clinical policy. Previously, a new iv administration set was used each time a dose of medication was infused to prevent the need for HCWs to recap the contaminated needle on the infusion set. With the institution of the needleless iv system, the blunt cannula used with the system was recapped and the set reused for a single patient for up to 24 hours. This new policy resulted in a savings from the reduction in the number of new iv administration sets required for each patient.

Jagger et al. proposed another type of analysis to determine the cost effectiveness of needleless or protected needle devices.[95] They considered the six major needled devices—disposable syringe and needle, iv tubing/needle assembly, prefilled cartridge syringe, winged steel needle iv set, vacuum tube phlebotomy set, and iv catheter stylet—used at their institution and compared the total cost of all needlestick injuries associated with each device with the total cost of the device producing the injuries. The cost estimates for 1988 were calculated from the number of injuries that occurred with each type of device, the cost of treating injured HCWs, and the total cost of each item to the hospital (price per item times number of items purchased). For the six needled devices, the cost of the average needlestick was $405 (1988 U. S. dollars), ranging from $390 for a needlestick associated with a disposable syringe to $456 for an injury from an iv catheter stylet. The total cost of needlestick injuries with a specific device as a percent of the total cost of the item to the hospital ranged from 10% for an iv catheter (a relatively expensive item) to 457% for a needle used to connect iv tubing (an inexpensive item). The total cost of all needlestick injuries ($138,023) equalled 36% of the total cost of all six devices purchased by the hospital ($378,811). This analysis suggests that, on average, if 100% of needlestick injuries associated with a needled device were eliminated by use of a comparable needleless or protected needle item, the new safety device would be cost effective if its price was not more than 36% above that of the original needled or non-protected item. Each hospital could perform its own cost analyses based on the specific data from the institution.

OSHA has directed employers to use engineering controls when applicable to reduce employees' risk of exposure to blood and body fluids.‡ Since needlestick injuries accounted for one-third of all reported work-related accidents in one hospital survey,[96] hospitals must consider their liability if unprotected needled devices are furnished for HCWs' use when comparable needleless or protected needle items are commercially available.

The annual cost of materials associated with the implementation of universal precautions at one university-affiliated hospital was $350,900.[97] Approximately two-thirds of this total represented the cost of gloves, and one-quarter was for disposable gowns. In this instance, the majority of the funds expended to protect HCWs were for gloves and gowns, although in most reports, the majority of cases of occupationally acquired infections (especially HIV) result from needlesticks or sharp injuries that are not prevented by these items. This suggests that more resources need to be devoted to devices that prevent percutaneous injuries.

Possible Complications from Needleless or Protected Needle Devices

Whenever new equipment is introduced into widespread clinical practice, unexpected complications may occur that were not observed in limited trials. Practitioners may use the new items without a thorough understanding of the manufacturer's warnings or use the devices in situations that were not studied during laboratory or clinical testing.

Two cases have been reported of air entrainment through valved manifolds that were used to replace conventional iv injection sites.[89,90] In these cases, which occurred during cardiopulmonary bypass, the injection ports were in iv tubing connected to a catheter in a central vein. The very low or negative central venous pressure created by the venous return bypass system was adequate to open an otherwise competent valve on the manifold. Since dead-end caps were not covering the ports, air was entrained. It seems possible that other clinical situations that would produce a low central venous pressure could result in air entrainment through the valved devices if the ports are not occluded by a dead-end cap. If practitioners are unaware of this risk, air embolism might be an unexpected complication of the new products that were introduced to protect the anesthesiologist from needlestick injuries.

Dryden demonstrated that stopcocks used in patients' iv tubing were often contaminated despite educational efforts directed at anesthesia personnel.[98] Stopcock ports were left uncovered and often were touched by nonsterile surfaces or personnel's fingers. It is likely that open ports of manifolds may be handled in the same manner during clinical practice, a scenario that may put patients at risk for systemic infection.

As needleless and protected needle devices gain widespread use, it is critical that both worker and patient complications be monitored so that these can be corrected through improved product design or better training of practitioners.

Summary

Anesthesiologists are at risk for acquiring blood-borne infections through contact with blood or body fluids.[99] From prospective studies, the greatest risk of transmission is through a percutaneous exposure such as needlestick injury. Personal protective equipment such as gloves and gowns do not completely prevent these exposures. Although educational efforts can reduce the frequency of recapping of needles, they generally have not decreased the incidence of needlesticks. Therefore, in addition to practicing universal precautions, anesthesiologists can attempt to reduce their risk of needlestick injuries by eliminating nonessential unprotected needle use, through the use of needleless or protected needle devices (engineering controls) and by modifying anesthetic procedures requiring needles (work practice controls). Needleless or protected needle products are commercially available for use in many procedures performed by anesthesiologists. For tasks that require the use of needled devices, the practitioner should use safe techniques for handling (i.e., one-handed recapping if recapping is needed) and disposal (i.e., puncture-resistant containers) of these devices. Evaluation of the efficacy, cost, and safety of needleless or protected needle products should be continued as they are introduced into wider use. Additionally, anesthesiologists should be encouraged to report needlestick injuries so that appropriate postexposure treatment can be given and so that the incident can be studied to permit design of a work protocol or device to prevent similar accidents in the future.

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Appendix: Examples of Needleless or Protected Needle Products and Manufacturers

Intravenous Catheters and Needles
  Intima™, Deseret Medical Inc., Becton Dickinson and Co.
  Landmark®, Menlo Care, Inc.
  ProtectIV™, Critikon Inc.
  Shamrock™, Ryan Medical Inc.
Devices for Intravenous Administration of Medications
  Auto-Lock™, Block Medical
  Click Lock™, ICU Medical Inc.
  InterLink IV Access System™, Baxter Healthcare Corporation
  Needle-Lock™, Baxter Healthcare Corporation
  SafSite™, Burron Medical Inc.
  Saf-T Clik® Protected Needle Adapter, Ryan Medical Inc.
Multiport Manifolds for Intravenous Administration of Medications
  Burron SafSite™ Anesthesia System, Burron Medical Inc.
  Connecta® Multiflo, Viggo-Spectramed
  Medifold™, Medex
  Quest Anesthesia Sets, Quest Medical
  Safeport™, L&W Technology Inc.
Devices to Access the Contents of Multidose Vials
  Complete Needleless Medication Access System, Burron Medical Inc.
  InterLink Access System™, Baxter Healthcare Corporation
  Safe-Draw™, Edge Medical
Syringes and Sheaths that Protect Attached Needles
  Monoject®, Sherwood Medical Company
  Safety-Lok™ Syringe, Becton Dickinson and Co.
  Safe-Point™ Needle and Cover System, North American Medical Products
  Sterimatic Safety Needle, Sterimatic Medical Systems, Ltd.
Recapping Devices
  Needle Scabbard, Scabbard Research Inc.
  OMED Syringe Stand/Recap Pad, Oxboro Medical International
  On-Gard Recapper™, On-Gard Systems Inc.
Blood Collection Devices
  Interlink™, Baxter Healthcare Corporation
  Safedraw™, Viggo-Spectramed
  Saf-T-Clik® Shielded Blood Needle Adapter, Ryan Medical Inc.
  VAMP™, Venous/Arterial Blood Management Protection System, Baxter Healthcare Corporation