



**ESRD Update:
Transitioning to New ESRD Conditions for Coverage
Student Manual**

Lesson #4: Infection Control/Physical Environment

Learning Objectives

At the conclusion of this lesson, you will be able to demonstrate understanding of:

- The new infection control regulations
- Changes from the “old” to the “new” regulations
- Tags to cite survey findings

Condition: Infection Control

Kelly Frank and Rosemarie Miller

1

Objectives

Demonstrate understanding of:

- The new infection control regulations
- Changes from the "old" to the "new" regulations
- Tags to cite survey findings

2

CELEBRATE GOOD TIMES COME ON!!!

- Prior
 - 2 tags to cite deficiencies
- Now
 - 29 specific tags to cite deficiencies in the Infection Control COP



Do the Happy Dance!!!

3

Infection Control

- Infection Control regulations – apply to both chronic in-center dialysis & home dialysis programs
- Incorporated CDC documents:
 - RR-05: *Recommendations for Preventing Transmission of Infections Among Chronic HD patients*
 - RR-10: *Guidelines for the Prevention of Intravascular Catheter-Related Infections*

4

Environment/IC Program

- Sanitary environment in the dialysis facility & between the unit & other areas (V111)
- Components of an infection control program (V112)

5

Gloves & Hand Hygiene

"Hand washing is the most important measure to prevent contaminant transmission."--CDC

V113 requires:

- Wear gloves – Whenever caring for a patient or touching the patient's equipment.
- Remove/change gloves – Must perform hand hygiene after removal of gloves between each patient or station.

6

Gloves & Hand Hygiene

- Hand hygiene
 - Use soap & water or alcohol-based antiseptic hand rub
 - Visibly soiled vs. not visibly soiled
- Intravascular catheters
 - Staff should wear clean or sterile gloves when changing the dressing on IV catheters
 - Hand hygiene performed before & after palpating catheter insertion sites, as well as before & after accessing or dressing an IV catheter

7

Sinks with Warm Water & Soap

V114 Requires:

- Sinks must be available & easily accessible to facilitate hand washing
 - Includes in the patient treatment area, reuse room, medication area, home training room, & isolation area/room
 - Sinks must be supplied with both hot & cold water
 - Uncontaminated supply of paper towels available

Expect:

- Dedicated hand washing sinks
- Designated utility sinks
- Sink available for patients to wash hands & access sites

8

PPE: Must Wear Gowns

V115 requires:

- A gown or lab coat must be worn when the spurting or spattering of blood, body fluids, potentially-contaminated substances or chemicals might occur
 - Aprons are not sufficient PPE during procedures that may result in the spurting or spattering of blood
- Clarifies when staff, patients, & visitors should wear PPE & when the PPE should be changed

9

Items Taken Into the Dialysis Station

V116 requires:

- Items taken into the dialysis station
 - Dispose, dedicate, or clean & disinfect
 - Unused supplies or medications should not be returned to a common area or used on other patients

10

Clean/Dirty Areas & Medication Preparation Areas

V117 requires:

- Separate clean from contaminated areas
- Prepare individual patient meds in a centralized area away from the treatment area
 - Designate area only for medication prep
 - Deliver separately to each patient
- Do not move the medication cart from patient station to patient station to deliver medications
- If trays are used, clean between patients

11

Single Use Vials = Single Use

V118 requires:

- Single dose vials **cannot** be punctured more than once
 - Must be used for only one patient
 - Not entered more than once
 - If entered, may not be stored for future use.
- BRAND NEW: MMWR August 15, 2008 retracts the 2002 CDC communication allowing multiple use of single use vials**
- Multi-use vials: residual medication from two or more vials must not be pooled into a single vial

12

Supply Cart & Supplies

V119 requires:

- If a common supply cart is used, do not move the cart from patient station to patient station to deliver supplies
- Do not carry supplies, patient care items, or medications in pockets

13

Transducer Protectors

V120 requires:

- External venous & arterial pressure transducer filters/protectors
 - Use for each patient treatment
 - Change between each patient
 - Change if it becomes "wet"
- If the external transducer protector becomes wet
 - Replace immediately & inspect
 - If fluid visible, qualified personnel must inspect inside of the dialysis machine after that patient treatment
 - If contaminated occurred, machine must be taken out of service & disinfected

14

Handling Infectious Waste

V121 requires:

- Handling, storage, & disposal of potentially infectious waste infectious waste
 - Be aware of your State & local laws

15

Cleaning & Disinfecting of Contaminated Surfaces, Medical Devices, & Equipment

V122 requires:

- Protocols for cleaning & disinfecting surfaces & equipment
 - Manufacturer's DFUs followed
 - CDC recommended disinfection procedures
- Cleaning & disinfection of environmental surfaces completed between patient uses
 - Chairs, beds, machines & containers associated with prime waste, adjacent tables & work surfaces

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Cleaning & Disinfecting of Contaminated Surfaces, Medical Devices, & Equipment

V122 requires:

- Clean & disinfect medical devices & equipment after each patient
 - Scissors, hemostats, clamps, stethoscopes, blood pressure cuffs
- Blood spills cleaned effectively & immediately
 - "Intermediate-level" disinfectant

17

Hepatitis B Routine Testing, Vaccination, Screening, & Seroconversion (V124-127)

- Routine testing for HBV (V124)
 - HBV status of all patients known before admission to the HD unit
 - Test all patients as required by the CDC schedule
- Results of HBV testing promptly reviewed (V125)
- Vaccination of susceptible patients & staff members (V126)
 - All susceptible patients & staff are offered hepatitis B vaccination

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Hepatitis B Routine Testing, Vaccination, Screening, & Seroconversion

- Test for response to the Hepatitis B vaccine (V127)
- Seroconversion (V125)
 - Reported to the State or local health department
 - Isolation of the seroconverted patient
 - Review all patients' lab test results for seroconversion

19

HBV+ Isolation Room/Area

V128 & V129: Isolation of HBV+ Patients

- Effective Feb 9, 2009, every new facility MUST include an isolation room for treatment of HBV+ patients, unless the facility is granted a waiver of this requirement
- For existing units in which a separate room is not possible, there must be a separate area for HBsAg positive patients

20

Isolation of HBV+ Patients

- Dedicated machines, equipment, supplies, & medications (V130)
 - Used only for HBV+ patients until patient is discharged from facility
- Staff assigned to care for HBV+ patient (V131):
 - May only care for other HBV+ patients or
 - HBV immune patients

21

Staff Training & Education

V132

- Infection Control Training & Education
 - Required for both new & existing staff members

V147

- Education & training for care of IV catheters

22

Oversight for Infection Control Practices/ Program & Reporting Requirements

- Biohazard & infection control policies & activities (V142)
- Compliance with current aseptic techniques in IV medication dispensing & administration (V143)
- Reporting of infection control issues to the medical director & QAPI committee (V144)
- Reporting communicable diseases (V145)

23

IV Catheter Care & Maintenance

V146-148

- Adopts RR-10 CDC recommendations related to catheters as regulation (V146)
- Monitor catheter sites (V147)
- Conduct surveillance for catheter related infections (V148)

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Clicker Question!!!

- A staff member initiating a dialysis treatment may use an apron for PPE.
A. True
B. False

25

Clicker Question!!!

- After Feb 9, 2009, every dialysis facility must add an isolation room.
A. True
B. False

26

Clicker Question!!!

- Single use vials may be re-entered till the last drop of medication is gone.
A. True
B. False

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**Condition:
Physical
Environment**

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Physical Environment

Includes:

- 2000 Addition of Life Safety Code (LSC) of National Fire Protection Association (NFPA)
 - Ambulatory Health Care Occupancy
 - Fire safety: sprinklers/waivers
- Emergency Preparedness
 - Staff training
 - CPR certification
 - Defibrillator/AED

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Physical Environment

Organized around:

- Building
- Equipment
- Environment

30

Building: Safe (V401-402)

- No obstacles (risks for falls)(V401)
- Intact surfaces (no loose tiles or broken work surfaces) (V401)
- Only authorized persons admitted (doors not propped open) (V402)
- Meets State, local building codes (V402)

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Safe & Functional Equipment: V403

Hemodialysis Delivery Systems:

- Safety checks done before use
- Transducer protectors used & changed appropriately
- Functional monitors & alarms
- Heparin pumps maintained
- PMs in accordance with DFU
- Home patients' equipment included

No "Dummy Drip Chambers"

32

Safe & Functional Equipment (V403)

- Water treatment system*
- Reuse system*
- Ancillary Equipment
- Emergency Equipment
- Furniture

*Problems in these areas should be cited in those specific Conditions

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Emergency Equipment: V413

On premises & immediately available:

- Defibrillator or AED
- Suction
- Oxygen
- Airways
- Ambu bag
- Emergency drugs

And

- Emergency evacuation supplies (V408)

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Safe & Functional Environment

- Operational (lighting, heating, air conditioning, space) (V401)
- Sufficient space for patient treatment (V404) & privacy (V406)
- Temperature: accommodate staff & patient needs (V405)
- Patient must be in view of staff during the HD treatment (video surveillance does not meet this requirement). Includes expectation that access sites & bloodline connections will not be covered. (V407)

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Clicker Question!!!

- A dialysis facility is not required to have:

- A. Defibrillator or AED
- B. Suction & Ambu bag
- C. Emergency medications
- D. Emergency Generator

36

Clicker Question!!!

- “Covered access” can be cited under the Condition of:
 - A. Infection Control
 - B. Physical Environment
 - C. Personnel Qualifications
 - D. Care at Home

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Infection Control & Physical Environment

Questions?

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Resources

Infection Control Requirements for Dialysis Facilities and Clarification Regarding Guidance on Parenteral Medication Vials

In April 2008, the Centers for Medicare and Medicaid Services (CMS) published in the *Federal Register* its final rule on *Conditions for Coverage for End-Stage Renal Disease (ESRD) Facilities* (1). The rule establishes new conditions dialysis facilities must meet to be certified under the Medicare program and is intended to update CMS standards for delivery of quality care to dialysis patients. CDC's 2001 *Recommendations for Preventing Transmission of Infections among Chronic Hemodialysis Patients* (2) have been incorporated by reference into the new CMS conditions for coverage. Thus, effective October 14, 2008, all ESRD facilities are expected to follow the CDC recommendations as a condition for receiving Medicare payment for outpatient dialysis services.

In recent years, outbreak investigations in dialysis and other health-care settings have demonstrated that mishandling of parenteral medication vials can contribute to the risk for hepatitis C virus (HCV) infection and bacterial and other infections (3--7). In 2002, a CDC communication to CMS suggested that reentry into single-use parenteral medication vials (i.e., to administer medication to more than one patient), when performed on a limited basis and under strict conditions in hemodialysis settings, likely would result in low risk for bacterial infection (8). However, the 2002 communication did not address risks for bloodborne viral infections (e.g., HCV and hepatitis B virus infection). This report is intended to clarify and restate CDC's recommendation on parenteral medication to include bloodborne viral infections. The recommendations in this report supersede the 2002 CDC communication to CMS.

To prevent transmission of both bacteria and bloodborne viruses in hemodialysis settings, CDC recommends that all single-use injectable medications and solutions be dedicated for use on a single patient and be entered one time only. Medications packaged as multidose should be assigned to a single patient whenever possible. All parenteral medications should be prepared in a clean area separate from potentially contaminated items and surfaces. In hemodialysis settings where environmental surfaces and medical supplies are subjected to frequent blood contamination, medication preparation should occur in a clean area removed from the patient treatment area. Proper infection control practices must be followed during the preparation and administration of injected medications (9). This is consistent with official CDC recommendations for infection control precautions in hemodialysis (2) and other health-care settings (9).

Health departments and other public health partners should be aware of the new CMS conditions for ESRD facilities. All dialysis providers are advised to follow official CDC recommendations regarding Standard Precautions and infection control in dialysis settings (2,9). Specifically, CDC has recommended the following: "Intravenous medication vials labeled for single use, including erythropoietin, should not be punctured more than once. Once a needle has entered a vial labeled for single use, the sterility of the product can no longer be guaranteed" (2). Additional guidance on safe injection practices can be found in the *Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings 2007* (9).

Dialysis providers also should be aware of their responsibility to report clusters of infections or other adverse events to the appropriate local or state public health authority. Failure to report illness clusters to public health authorities can result in delays in recognition of disease outbreaks (10) and implementation of control measures. Additional

information regarding the new CMS *Conditions for Coverage for End-Stage Renal Disease Facilities* is available at http://www.cms.hhs.gov/cfcsandcops/13_esrd.asp.

References

1. US Department of Health and Human Services. Centers for Medicare and Medicaid Services. Medicare and Medicaid programs; conditions for coverage for end-stage renal disease facilities. 42 CFR Parts 405, 410, 413, 414, 488, and 494. Available at <http://www.cms.hhs.gov/cfcsandcops/downloads/esrdfinalrule0415.pdf>
2. [CDC. Recommendations for preventing transmission of infections among chronic hemodialysis patients. MMWR 2001;50\(No. RR-5\).](#)
3. Thompson N, Bialek S. Hepatitis C virus transmission in the hemodialysis setting: importance of infection control practices and aseptic technique [Abstract]. In: programs and abstracts of the National Kidney Foundation Spring Meeting; April 3, 2008; Grapevine, TX.
4. [CDC. Acute hepatitis C virus infections attributed to unsafe injection practices at an endoscopy clinic---Nevada, 2007. MMWR 2008;57: 513--7.](#)
5. Williams IT, Perz JF, Bell BP. Viral hepatitis transmission in ambulatory health care settings. *Clin Infect Dis* 2004;38:1592--8.
6. Alter MJ. Healthcare should not be a vehicle for transmission of hepatitis C virus. *J Hepatol* 2008;48:2--4.
7. Grohskopf LA, Roth VR, Feikin DR, et al. *Serratia liquefaciens* bloodstream infections from contamination of epoetin alfa at a hemodialysis center. *N Engl J Med* 2001;344:1491--7.
8. Department of Health and Human Services. Centers for Medicare and Medicaid Services. CDC revised recommendations for single-use intravenous medication vials in end-stage renal disease (ESRD) facilities, 2002. Available at <http://www.cms.hhs.gov/surveycertificationgeninfo/downloads/scletter02-43.pdf>.
9. Siegel JD, Rhinehart E, Jackson M, Chiarello L, and the Healthcare Infection Control Practices Advisory Committee. Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings 2007. Atlanta, GA: US Department of Health and Human Services, CDC; 2007. Available at http://www.cdc.gov/ncidod/dhqp/gl_isolation.html.
10. [CDC. Acute allergic-type reactions among patients undergoing hemodialysis---multiple states, 2007--2008. MMWR 2008;57:124--5.](#)

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Department of Health
and Human Services

**Recommendations for Preventing
Transmission of Infections Among
Chronic Hemodialysis Patients**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention (CDC)
Atlanta, GA 30333



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Terms and Abbreviations Used in This Publication

Acute hepatitis B	Newly acquired symptomatic hepatitis B virus (HBV) infection.
Acute hepatitis C	Newly acquired symptomatic hepatitis C virus (HCV) infection.
ALT	Alanine aminotransferase, previously called SGPT.
Anti-HBc	Antibody to hepatitis B core antigen.
Anti-HBe	Antibody to hepatitis B e antigen.
Anti-HBs	Antibody to hepatitis B surface antigen.
Anti-HCV	Antibody to hepatitis C virus.
Anti-HDV	Antibody to hepatitis D virus.
AST	Aspartate aminotransferase, previously called SGOT.
AV	Arteriovenous.
Chronic (persistent) HBV infection	Persistent infection with HBV; characterized by detection of HBsAg >6 months after newly acquired infection.
Chronic (persistent) HCV infection	Persistent infection with HCV; characterized by detection of HCV RNA >6 months after newly acquired infection.
Chronic hepatitis B	Liver inflammation in patients with chronic HBV infection; characterized by abnormal levels of liver enzymes.
Chronic hepatitis C	Liver inflammation in patients with chronic HCV infection; characterized by abnormal levels of liver enzymes.
CNS	Coagulase negative staphylococci.
EIA	Enzyme immunoassay.
EPA	U.S. Environmental Protection Agency.
ESRD	End-stage renal disease.
FDA	U.S. Food and Drug Administration.
GISA	Glycopeptide-resistant <i>Staphylococcus aureus</i> .
HBcAg	Hepatitis B core antigen
HBeAg	Hepatitis B e antigen.
HBsAg	Hepatitis B surface antigen.
HBV	Hepatitis B virus.
HBV DNA	Hepatitis B virus deoxyribonucleic acid.
HCV	Hepatitis C virus.
HCV RNA	Hepatitis C virus ribonucleic acid.
HDV	Hepatitis D virus.
HIV	Human immunodeficiency virus.
Isolated anti-HBc	Anti-HBc positive, HBsAg negative, and anti-HBs negative.
MRSA	Methicillin-resistant <i>Staphylococcus aureus</i> .
NNIS	National Nosocomial Infections Surveillance system.
RIBA™	Recombinant immunoblot assay.
RT-PCR	Reverse transcriptase polymerase chain reaction.
SGOT	Serum glutamic-oxaloacetic transaminase, now called AST.
SGPT	Serum glutamic-pyruvic transaminase, now called ALT.
VISA	Vancomycin-intermediate <i>Staphylococcus aureus</i> .
VRE	Vancomycin-resistant enterococci.

**Consultant Meeting to Update Recommendations for the
Prevention and Control of Bloodborne and Other Infections
Among Chronic Hemodialysis Patients**

**October 5–6, 1999
Atlanta, Georgia**

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Recommendations for Preventing Transmission of Infections Among Chronic Hemodialysis Patients

Summary

These recommendations replace previous recommendations for the prevention of bloodborne virus infections in hemodialysis centers and provide additional recommendations for the prevention of bacterial infections in this setting. The recommendations in this report provide guidelines for a comprehensive infection control program that includes a) infection control practices specifically designed for the hemodialysis setting, including routine serologic testing and immunization; b) surveillance; and c) training and education. Implementation of this program in hemodialysis centers will reduce opportunities for patient-to-patient transmission of infectious agents, directly or indirectly via contaminated devices, equipment and supplies, environmental surfaces, or hands of personnel. Based on available knowledge, these recommendations were developed by CDC after consultation with staff members from other federal agencies and specialists in the field who met in Atlanta on October 5–6, 1999. They are summarized in the Recommendations section. This report is intended to serve as a resource for health-care professionals, public health officials, and organizations involved in the care of patients receiving hemodialysis.

INTRODUCTION

The number of patients with end-stage renal disease treated by maintenance hemodialysis in the United States has increased sharply during the past 30 years. In 1999, more than 3,000 hemodialysis centers had >190,000 chronic hemodialysis patients and >60,000 staff members (1). Chronic hemodialysis patients are at high risk for infection because the process of hemodialysis requires vascular access for prolonged periods. In an environment where multiple patients receive dialysis concurrently, repeated opportunities exist for person-to-person transmission of infectious agents, directly or indirectly via contaminated devices, equipment and supplies, environmental surfaces, or hands of personnel. Furthermore, hemodialysis patients are immunosuppressed (2), which increases their susceptibility to infection, and they require frequent hospitalizations and surgery, which increases their opportunities for exposure to nosocomial infections.

Historically, surveillance for infections associated with chronic hemodialysis focused on viral hepatitis, particularly hepatitis B virus (HBV) infection. CDC began conducting national surveillance for hemodialysis-associated hepatitis in 1972 (3,4). Since 1976, this surveillance has been performed in collaboration with the Health Care Financing Administration (HCFA) during its annual facility survey. Other hemodialysis-associated diseases and practices not related to hepatitis have been included over the years (e.g., pyrogenic reactions, dialysis dementia, vascular access infections, reuse practices, vancomycin use), and the system is continually updated to collect data regarding hemodialysis-associated practices and diseases of current interest and importance (5–18).

Recommendations for the control of hepatitis B in hemodialysis centers were first published in 1977 (19), and by 1980, their widespread implementation was associated with a sharp reduction in incidence of HBV infection among both patients and staff members (5). In 1982, hepatitis B vaccination was recommended for all susceptible patients and staff members (20). However, outbreaks of both HBV and hepatitis C virus (HCV) infections continue to occur among chronic hemodialysis patients. Epidemiologic investigations have indicated substantial deficiencies in recommended infection control practices, as well as a failure to vaccinate hemodialysis patients against hepatitis B (21,22). These practices apparently are not being fully implemented because staff members a) are not aware of the practices and their importance, b) are confused regarding the differences between standard (i.e., universal) precautions recommended for all health-care settings and the additional precautions necessary in the hemodialysis setting, and c) believe that hepatitis B vaccine is ineffective for preventing HBV infection in chronic hemodialysis patients (22).

Bacterial infections, especially those involving vascular access, are the most frequent infectious complication of hemodialysis and a major cause of morbidity and mortality among hemodialysis patients (1). During the 1990s, the prevalence of antimicrobial-resistant bacteria (e.g., methicillin-resistant *Staphylococcus aureus* [MRSA] and vancomycin-resistant enterococci [VRE]) increased rapidly in health-care settings, including hemodialysis units (18,23). Although numerous outbreaks of bacterial infections in the hemodialysis setting have been reported (24), few studies exist regarding the epidemiology and prevention of endemically occurring bacterial infections in hemodialysis patients, and formal recommendations to prevent such infections have not been published previously. In 1999, CDC initiated a surveillance system for bloodstream and vascular access infections in outpatient hemodialysis centers to determine the frequency of and risk factors for these complications in order to formulate and evaluate strategies for control (25).

The recommendations contained in this report were developed by reviewing available data and are based on consultations with specialists in the field. These recommendations provide guidelines for infection control strategies, unique to the hemodialysis setting, that should be used to prevent patient-to-patient transmission of bloodborne viruses and pathogenic bacteria. They are summarized on pages 20–21.

These recommendations do not address sources of bacterial and chemical contaminants in dialysis systems, water treatment or distribution, specific procedures for reprocessing dialyzers, clinical practice methods to prevent bacterial infections (e.g., techniques for skin preparation and access), or comprehensive strategies for preventing infections among health-care workers (see Suggested Readings for information on these topics).

BACKGROUND

Hepatitis B Virus Infection

Epidemiology

Incidence and Prevalence. In 1974, the incidence of newly acquired (i.e., acute) HBV infection among chronic hemodialysis patients in the United States was 6.2%, and se-

lected hemodialysis centers reported rates as high as 30% (4). By 1980, nationwide incidence among patients had decreased to 1% (5), and by 1999, to 0.06% (18) (CDC, unpublished data, 2001), with only 3.5% of all centers reporting newly acquired infections. Prevalence of chronic HBV infection (i.e., hepatitis B surface antigen [HBsAg] positivity) among hemodialysis patients declined from 7.8% in 1976 to 3.8% in 1980 and to 0.9% by 1999 (5,18) (CDC, unpublished data, 2001). In 1999, a total of 27.7% of 3,483 centers provided dialysis to ≥ 1 patient with either acute or chronic HBV infection (CDC, unpublished data, 2001).

Transmission. HBV is transmitted by percutaneous (i.e., puncture through the skin) or permucosal (i.e., direct contact with mucous membranes) exposure to infectious blood or to body fluids that contain blood, and the chronically infected person is central to the epidemiology of HBV transmission. All HBsAg-positive persons are infectious, but those who are also positive for hepatitis B e antigen (HBeAg) circulate HBV at high titers in their blood (10^{8-9} virions/mL) (26,27). With virus titers in blood this high, body fluids containing serum or blood also can contain high levels of HBV and are potentially infectious. Furthermore, HBV at titers of 10^{2-3} virions/mL can be present on environmental surfaces in the absence of any visible blood and still result in transmission (28,29).

HBV is relatively stable in the environment and remains viable for at least 7 days on environmental surfaces at room temperature (29). HBsAg has been detected in dialysis centers on clamps, scissors, dialysis machine control knobs, and doorknobs (30). Thus, blood-contaminated surfaces that are not routinely cleaned and disinfected represent a reservoir for HBV transmission. Dialysis staff members can transfer virus to patients from contaminated surfaces by their hands or gloves or through use of contaminated equipment and supplies (30).

Most HBV infection outbreaks among hemodialysis patients were caused by cross-contamination to patients via a) environmental surfaces, supplies (e.g., hemostats, clamps), or equipment that were not routinely disinfected after each use; b) multiple dose medication vials and intravenous solutions that were not used exclusively for one patient; c) medications for injection that were prepared in areas adjacent to areas where blood samples were handled; and d) staff members who simultaneously cared for both HBV-infected and susceptible patients (21,31–35). Once the factors that promote HBV transmission among hemodialysis patients were identified, recommendations for control were published in 1977 (19). These recommendations included a) serologic surveillance of patients (and staff members) for HBV infection, including monthly testing of all susceptible patients for HBsAg; b) isolation of HBsAg-positive patients in a separate room; c) assignment of staff members to HBsAg-positive patients and not to HBV-susceptible patients during the same shift; d) assignment of dialysis equipment to HBsAg-positive patients that is not shared by HBV-susceptible patients; e) assignment of a supply tray to each patient (regardless of serologic status); f) cleaning and disinfection of nondisposable items (e.g., clamps, scissors) before use on another patient; g) glove use whenever any patient or hemodialysis equipment is touched and glove changes between each patient (and station); and h) routine cleaning and disinfection of equipment and environmental surfaces.

The segregation of HBsAg-positive patients and their equipment from HBV-susceptible patients resulted in 70%–80% reductions in incidence of HBV infection among hemodialysis patients (7,36–38). National surveillance data for 1976–1989 indicated that incidence of HBV infection was substantially lower in hemodialysis units

that isolated HBsAg-positive patients, compared with those that did not (7,10). The success of isolation practices in preventing transmission of HBV infection is linked to other infection control practices, including routine serological surveillance and routine cleaning and disinfection. Frequent serologic testing for HBsAg detects patients recently infected with HBV quickly so isolation procedures can be implemented before cross-contamination can occur. Environmental control by routine cleaning and disinfection procedures reduces the opportunity for cross-contamination, either directly from environmental surfaces or indirectly by hands of personnel.

Despite the current low incidence of HBV infection among hemodialysis patients, outbreaks continue to occur in chronic hemodialysis centers. Investigations of these outbreaks have documented that HBV transmission resulted from failure to use recommended infection control practices, including a) failure to routinely screen patients for HBsAg or routinely review results of testing to identify infected patients; b) assignment of staff members to the simultaneous care of infected and susceptible patients; and c) sharing of supplies, particularly multiple dose medication vials, among patients (21). In addition, few patients had received hepatitis B vaccine (21). National surveillance data have demonstrated that independent risk factors among chronic hemodialysis patients for acquiring HBV infection include the presence of ≥ 1 HBV-infected patient in the hemodialysis center who is not isolated, as well as a $< 50\%$ hepatitis B vaccination rate among patients (15).

HBV infection among chronic hemodialysis patients also has been associated with hemodialysis provided in the acute-care setting (21,39). Transmission appeared to stem from chronically infected HBV patients who shared staff members, multiple dose medication vials, and other supplies and equipment with susceptible patients. These episodes were recognized when patients returned to their chronic hemodialysis units, and routine HBsAg testing was resumed. Transmission from HBV-infected chronic hemodialysis patients to patients undergoing hemodialysis for acute renal failure has not been documented, possibly because these patients are dialyzed for short durations and have limited exposure. However, such transmission could go unrecognized because acute renal failure patients are unlikely to be tested for HBV infection.

Clinical Features and Natural History

HBV causes both acute and chronic hepatitis. The incubation period ranges from 45–160 days (mean: 120 days), and the onset of acute disease is usually insidious. Infants, young children (aged < 10 years), and immunosuppressed adults with newly acquired HBV infection are usually asymptomatic (40). When present, clinical symptoms and signs might include anorexia, malaise, nausea, vomiting, abdominal pain, and jaundice. Extrahepatic manifestations of disease (e.g., skin rashes, arthralgias, and arthritis) can also occur (41). The case fatality rate after acute hepatitis B is 0.5%–1%.

In adults with normal immune status, most (94%–98%) recover completely from newly acquired HBV infections, eliminating virus from the blood and producing neutralizing antibody that creates immunity from future infection (40,42). In immunosuppressed persons (including hemodialysis patients), infants, and young children, most newly acquired HBV infections result in chronic infection. Although the consequences of acute hepatitis B can be severe, most of the serious sequelae associated with the disease occur in persons in whom chronic infection develops. Although persons with chronic HBV infection are often asymptomatic, chronic liver disease develops in two-

thirds of these persons, and approximately 15%–25% die prematurely from cirrhosis or liver cancer (43–45).

Subtypes of HBV exist, and infection or immunization with one subtype confers immunity to all subtypes. However, reinfection or reactivation of latent HBV infection has been reported among certain groups of immunosuppressed patients, including those who have undergone renal transplant and those infected with human immunodeficiency virus (HIV) (46,47). These patients were positive for antibody to hepatitis B core antigen (anti-HBc), with or without antibody to HBsAg (anti-HBs), and subsequently developed detectable levels of HBsAg. The frequency with which this occurs is unknown.

Monotherapy with alpha interferon or lamivudine is approved by the U.S. Food and Drug Administration (FDA) to treat patients with chronic hepatitis B (48,49). Although the dosage of lamivudine should be modified based on creatinine clearance in patients with renal impairment, no additional dose modification is necessary after routine hemodialysis. The emergence of lamivudine-resistant variants has caused concern regarding long-term use of this drug.

Screening and Diagnostic Tests

Serologic Assays. Several well-defined antigen-antibody systems are associated with HBV infection, including HBsAg and anti-HBs; hepatitis B core antigen (HBcAg) and anti-HBc; and HBeAg and antibody to HBeAg (anti-HBe). Serologic assays are commercially available for all of these except HBcAg because no free HBcAg circulates in blood. One or more of these serologic markers are present during different phases of HBV infection (Table 1) (42).

TABLE 1. Interpretation of serologic test results for hepatitis B virus infection

HBsAg*	Serologic Markers			Interpretation
	Total Anti-HBc†	IgM [§] Anti-HBc	Anti-HBs [¶]	
–	–	–	–	Susceptible, never infected
+	–	–	–	Acute infection, early incubation**
+	+	+	–	Acute infection
–	+	+	–	Acute resolving infection
–	+	–	+	Past infection, recovered and immune
+	+	–	–	Chronic infection
–	+	–	–	False positive (i.e., susceptible), past infection, or “low-level” chronic infection
–	–	–	+	Immune if titer is ≥ 10 mIU/mL

* Hepatitis B surface antigen.

† Antibody to hepatitis B core antigen.

§ Immunoglobulin M.

¶ Antibody to hepatitis B surface antigen.

** Transient HBsAg positivity (lasting ≤ 18 days) might be detected in some patients during vaccination.

The presence of HBsAg is indicative of ongoing HBV infection and potential infectiousness. In newly infected persons, HBsAg is present in serum 30–60 days after exposure to HBV and persists for variable periods. Transient HBsAg positivity (lasting ≤ 18 days) can be detected in some patients during vaccination (50,51). Anti-HBc develops in all HBV infections, appearing at onset of symptoms or liver test abnormalities in acute HBV infection, rising rapidly to high levels, and persisting for life. Acute or recently acquired infection can be distinguished by presence of the immunoglobulin M (IgM) class of anti-HBc, which persists for approximately 6 months.

In persons who recover from HBV infection, HBsAg is eliminated from the blood, usually in 2–3 months, and anti-HBs develops during convalescence. The presence of anti-HBs indicates immunity from HBV infection. After recovery from natural infection, most persons will be positive for both anti-HBs and anti-HBc, whereas only anti-HBs develops in persons who are successfully vaccinated against hepatitis B. Persons who do not recover from HBV infection and become chronically infected remain positive for HBsAg (and anti-HBc), although a small proportion (0.3% per year) eventually clear HBsAg and might develop anti-HBs (45).

In some persons, the only HBV serologic marker detected is anti-HBc (i.e., isolated anti-HBc). Among most asymptomatic persons in the United States tested for HBV infection, an average of 2% (range: $<0.1\%$ –6%) test positive for isolated anti-HBc (52); among injecting-drug users, however, the rate is 24% (53). In general, the frequency of isolated anti-HBc is directly related to the frequency of previous HBV infection in the population and can have several explanations. This pattern can occur after HBV infection among persons who have recovered but whose anti-HBs levels have waned or among persons who failed to develop anti-HBs. Persons in the latter category include those who circulate HBsAg at levels not detectable by current commercial assays. However, HBV DNA has been detected in $<10\%$ of persons with isolated anti-HBc, and these persons are unlikely to be infectious to others except under unusual circumstances involving direct percutaneous exposure to large quantities of blood (e.g., transfusion) (54). In most persons with isolated anti-HBc, the result appears to be a false positive. Data from several studies have demonstrated that a primary anti-HBs response develops in most of these persons after a three-dose series of hepatitis B vaccine (55,56). No data exist on response to vaccination among hemodialysis patients with this serologic pattern.

A third antigen, HBeAg, can be detected in serum of persons with acute or chronic HBV infection. The presence of HBeAg correlates with viral replication and high levels of virus (i.e., high infectivity). Anti-HBe correlates with the loss of replicating virus and with lower levels of virus. However, all HBsAg-positive persons should be considered potentially infectious, regardless of their HBeAg or anti-HBe status.

Nucleic Acid Detection. HBV infection can be detected using qualitative or quantitative tests for HBV DNA. These tests are not FDA-approved and are most commonly used for patients being managed with antiviral therapy (49,57).

Hepatitis B Vaccine

Hepatitis B vaccine has been recommended for both hemodialysis patients and staff members since the vaccine became available in 1982 (20). By 1999, a total of 55% of patients and 88% of staff members had been vaccinated (18) (CDC, unpublished data, 2001). Two types of vaccine have been licensed and used in the United States: plasma-derived and recombinant. Plasma-derived vaccine is no longer available in the United

States, but is produced in several countries and used in many immunization programs worldwide. Recombinant vaccines available in the United States are Recombivax HB™ (Merck & Company, Inc., West Point, Pennsylvania) and Engerix-B® (SmithKline Beecham Biologicals, Philadelphia, Pennsylvania). Recombivax HB™ contains 10–40 µg of HBsAg protein per mL, whereas Engerix-B® contains 20 µg/mL.

Primary vaccination comprises three intramuscular doses of vaccine, with the second and third doses given 1 and 6 months, respectively, after the first. An alternative schedule of four doses given at 0, 1, 2, and 12 months to persons with normal immune status or at 0, 1, 2, and 6 months to hemodialysis patients has been approved for Engerix-B®.

Immunogenicity. The recommended primary series of hepatitis B vaccine induces a protective anti-HBs response (defined as ≥ 10 milli-International Units [mIU]/mL) in 90%–95% of adults with normal immune status. The major determinant of vaccine response is age, with the proportion of persons developing a protective antibody response declining to 84% among adults aged >40 years and to 75% by age 60 years (58,59). Other host factors that contribute to decreased immunogenicity include smoking, obesity, and immune suppression. Compared with adults with normal immune status, the proportion of hemodialysis patients who develop a protective antibody response after vaccination (with higher dosages) is lower. For those who receive the three-dose schedule, the median is 64% (range: 34%–88%) (60–65), and for those who receive the four-dose schedule, the median is 86% (range: 40%–98%) (66–72). Limited data indicate that concurrent infection with HCV does not interfere with development of protective levels of antibody after vaccination, although lower titers of anti-HBs have been reported after vaccination of HCV-positive patients compared with HCV-negative patients (65,73–75).

Some studies have demonstrated that higher antibody response rates could be achieved by vaccinating patients with chronic renal failure before they become dialysis dependent, particularly patients with mild or moderate renal failure. After vaccination with four 20 µg doses of recombinant vaccine, a protective antibody response developed in 86% of predialysis adult patients with serum creatinine levels ≤ 4.0 mg/dl (mean: 2.0 mg/dl) compared with 37% of those with serum creatinine levels >4.0 mg/dl (mean: 9.5 mg/dl), only 12% of whom were predialysis patients (76). In an earlier study, a lower response to recombinant vaccine among predialysis patients was reported, possibly because patients with more severe renal failure were included (77,78).

Although no data exist on the response of pediatric hemodialysis patients to vaccination with standard pediatric doses, 75%–97% of those who received higher dosages (20 µg) on either the three- or four-dose schedule developed protective levels of anti-HBs (79–81). In the one study that evaluated vaccine response among children with chronic renal failure before they became dialysis dependent, high response rates were achieved after four 20 µg doses in both predialysis and dialysis-dependent patients, although predialysis patients had higher peak antibody titers (82).

Vaccine Efficacy. For persons with normal immune status, controlled clinical trials have demonstrated that protection from acute and chronic HBV infection is virtually complete among those who develop a protective antibody response after vaccination (83,84). Among hemodialysis patients, controlled clinical trials conducted in other countries demonstrated efficacy of 53%–78% after preexposure immunization (85,86). However, no efficacy was demonstrated in the one trial performed in the United States (62). When the latter trial was designed, the sample size was calculated based on an annual

incidence rate among susceptible patients of 13.8% (i.e., the rate observed during 1976–1979, the period before the start of the trial). However, by the time the trial was conducted, the incidence rate had declined by >60%, and the sample size was inadequate for detecting a difference in infection rates between vaccinated and placebo groups. Although efficacy was not demonstrated in this study, no infections occurred among persons who developed and maintained protective levels of anti-HBs.

Furthermore, since the hepatitis B vaccine became available, no HBV infections have been reported among vaccinated hemodialysis patients who maintained protective levels of anti-HBs. This observation has been particularly striking during HBV infection outbreaks in this setting (21). In addition, a case-control study indicated that the risk for HBV infection was 70% lower among hemodialysis patients who had been vaccinated (87). Thus, most hemodialysis patients can be protected from hepatitis B by vaccination, and maintaining immunity among these patients reduces the frequency and costs of serologic screening (88).

Revaccination of Nonresponders. Among persons who do not respond to the primary three-dose series of hepatitis B vaccine, 25%–50% of those with normal immune status respond to one additional vaccine dose, and 50%–75% respond to three additional doses (59,84). A revaccination regimen that includes serologic testing after one or two additional doses of vaccine appears to be no more cost-effective than serologic testing performed after all three additional doses (89). For persons found to be nonresponders after six doses of vaccine, no data exist to indicate that additional doses would induce an antibody response. Few studies have been conducted of the effect of revaccination among hemodialysis patients who do not respond to the primary vaccine series. Response rates to revaccination varied from 40%–50% after two or three additional 40 µg intramuscular doses to 64% after four additional 10 µg intramuscular doses (69,70,90–94).

Antibody Persistence. Among adults with normal immune status who responded to a primary vaccine series with a protective antibody level, antibody remained above protective levels in 40%–87% of persons after 9–15 years (95–98). Only short-term data are available for hemodialysis patients. Among adults who responded to the primary vaccination series, antibody remained detectable for 6 months in 80%–100% (median: 100%) of persons and for 12 months in 58%–100% (median: 70%) (61,64–69,71,85,99–103). Among successfully immunized hemodialysis patients whose antibody titers subsequently declined below protective levels, limited data indicate that virtually all respond to a booster dose (75).

Duration of Vaccine-Induced Immunity. Among persons with normal immune status who respond to the primary series of hepatitis B vaccine, protection against hepatitis B persists even when antibody titers become undetectable (97). However, among hemodialysis patients who respond to the vaccine, protection against hepatitis B is not maintained when antibody titers fall below protective levels. In the U.S. vaccine efficacy trial, three hemodialysis patients who responded to the primary vaccination series developed HBV infection (62). One had received a kidney transplant 6 months before onset of infection, and anti-HBs had declined to borderline protective levels in the other two persons. In all three patients, infection resolved.

Alternative Routes of Administration. Among adults with normal immune status, intradermal administration of low doses of hepatitis B vaccine results in lower seroconversion rates (55%–81%) (104–106), and no data exist on long-term protection from this route of administration. Among infants and children, intradermal vaccination

results in poor immunogenicity. Data are insufficient to evaluate alternative routes (e.g., intradermal) for vaccination among hemodialysis patients.

Hepatitis C Virus Infection

Epidemiology

Incidence and Prevalence. Data are limited on incidence of HCV infection among chronic hemodialysis patients. During 1982–1997, the incidence of non-A, non-B hepatitis among patients reported to CDC's national surveillance system decreased from 1.7% to 0.2% (18). The validity of these rates is uncertain because of inherent difficulties in diagnosing non-A, non-B hepatitis and probable variability in the application of diagnostic criteria by different dialysis centers. However, the downward trend can partially be explained by a decline in the rate of transfusion-associated disease after 1985 (107,108).

Since 1990, limited data from U.S. studies using testing for antibody to HCV (anti-HCV) to evaluate the incidence of HCV infection have reported annual rates of 0.73%–3% among hemodialysis patients (109,110). None of the patients who seroconverted had received transfusions in the interim or were injecting-drug users.

During 1992–1999, national surveillance data indicated that the proportion of centers that tested patients for anti-HCV increased from 22% to 56% (18) (CDC, unpublished data, 2001). In 1999, nationwide prevalence of anti-HCV was 8.9%, with some centers reporting prevalences >40% (CDC, unpublished data, 2001). Other studies of hemodialysis patients in the United States have reported anti-HCV prevalences of 10%–36% among adults (109,111,112) and 18.5% among children (113).

Transmission. HCV is most efficiently transmitted by direct percutaneous exposure to infectious blood, and like HBV, the chronically infected person is central to the epidemiology of HCV transmission. Risk factors associated with HCV infection among hemodialysis patients include history of blood transfusions, the volume of blood transfused, and years on dialysis (114). The number of years on dialysis is the major risk factor independently associated with higher rates of HCV infection. As the time patients spent on dialysis increased, their prevalence of HCV infection increased from an average of 12% for patients receiving dialysis <5 years to an average of 37% for patients receiving dialysis ≥5 years (109,112,115).

These studies, as well as investigations of dialysis-associated outbreaks of hepatitis C, indicate that HCV transmission most likely occurs because of inadequate infection control practices. During 1999–2000, CDC investigated three outbreaks of HCV infection among patients in chronic hemodialysis centers (CDC, unpublished data, 1999 and 2000). In two of the outbreaks, multiple transmissions of HCV occurred during periods of 16–24 months (attack rates: 6.6%–17.5%), and seroconversions were associated with receiving dialysis immediately after a chronically infected patient. Multiple opportunities for cross-contamination among patients were observed, including a) equipment and supplies that were not disinfected between patient use; b) use of common medication carts to prepare and distribute medications at patients' stations; c) sharing of multiple dose medication vials, which were placed at patients' stations on top of hemodialysis machines; d) contaminated priming buckets that were not routinely changed or cleaned and disinfected between patients; e) machine surfaces that were not routinely cleaned and disinfected between patients; and f) blood spills that were

not cleaned up promptly. In the third outbreak, multiple new infections clustered at one point in time (attack rate: 27%), suggesting a common exposure event. Although the specific results of this investigation are pending, multiple opportunities for cross-contamination from chronically infected patients also were observed in this unit. In particular, supply carts were moved from one station to another and contained both clean supplies and blood-contaminated items, including small biohazard containers, sharps disposal boxes, and used vacutainers containing patients' blood.

Clinical Features and Natural History

HCV causes both acute and chronic hepatitis. The incubation period ranges from 14–180 days (average: 6–7 weeks) (116). Persons with newly acquired (acute) HCV infection typically are either asymptomatic or have a mild clinical illness. The course of acute hepatitis C is variable, although elevations in serum alanine aminotransferase (ALT) levels, often in a fluctuating pattern, are the most characteristic feature. Fulminant hepatic failure after acute hepatitis C is rare.

Most (average: 94%) hemodialysis patients with newly acquired HCV infection have elevated serum ALT levels (117–121). Elevations in serum ALT levels often precede anti-HCV seroconversion. Among prospectively followed transfusion recipients who developed acute HCV infection, elevated ALT levels preceded anti-HCV seroconversion (as measured by second generation assays) in 59%, and anti-HCV was detectable in most patients (78%) within 5 weeks after their first ALT elevation (122). However, elevations in ALT or aspartate aminotransferase (AST) levels can occur that are not related to viral hepatitis, and compared with ALT, AST is a less specific indicator of HCV-related liver disease among hemodialysis patients. In a recent outbreak investigation, only 28% of 25 hemodialysis patients with newly observed elevations in AST levels tested anti-HCV positive (CDC, unpublished data, 1999).

After acute HCV infection, 15%–25% of persons with normal immune status appear to resolve their infection without sequelae as defined by sustained absence of HCV RNA in serum and normalization of ALT (123). In some persons, ALT levels normalize, suggesting full recovery, but this is frequently followed by ALT elevations that indicate progression to chronic disease. Chronic HCV infection develops in most infected persons (75%–85%). Of persons with chronic HCV infection, 60%–70% have persistent or fluctuating ALT elevations, indicating active liver disease (123). Although similar rates of chronic liver disease have been observed among HCV-infected chronic hemodialysis patients (based on liver biopsy results), these patients might be less likely to have biochemical evidence of active liver disease (124). In seroprevalence studies of chronic hemodialysis patients, ALT elevations were reported in a median of 33.9% (range: 6%–73%) of patients who tested positive for anti-HCV (117,124–136).

No clinical or epidemiologic features among patients with acute infection have been reported to be predictive of either persistent infection or chronic liver disease. Most studies have reported that cirrhosis develops in 10%–20% of persons who have had chronic hepatitis C for 20–30 years, and hepatocellular carcinoma in 1%–5% (123). Extrahepatic manifestations of chronic HCV infection are considered to be of immunologic origin and include cryoglobulinemia, membranoproliferative glomerulonephritis, and porphyria cutanea tarda (137).

At least six different genotypes and >90 subtypes of HCV exist, with genotype 1 being the most common in the United States (138,139). Unlike HBV, infection with one

HCV genotype or subtype does not protect against reinfection or superinfection with other HCV strains (139).

Alpha interferon alone or in combination with ribavirin is FDA-approved for the treatment of chronic hepatitis C (48,140,141). Combination therapy should be used with caution in patients with creatinine clearance <50 mL/minute and generally is contraindicated in patients with renal failure (141,142). Interferon monotherapy results in low sustained virologic response rates (141,142).

Screening and Diagnostic Tests

Serologic Assays. The only FDA-approved tests for diagnosis of HCV infection are those that measure anti-HCV and include enzyme immunoassays (EIAs) and a supplemental recombinant immunoblot assay (RIBA™) (116). These tests detect anti-HCV in ≥97% of infected persons, but do not distinguish between acute, chronic, or resolved infection. The average time from exposure to seroconversion is 8–9 weeks (122). Anti-HCV can be detected in 80% of patients within 15 weeks after exposure, in ≥90% within 5 months, and in ≥97% within 6 months (122,143). In rare instances, seroconversion can be delayed until 9 months after exposure (143,144). Anti-HCV persists indefinitely in most persons, but does not protect against reinfection.

As with any screening test, the positive predictive value of EIAs for anti-HCV is directly related to the prevalence of infection in the population and is low in populations with an HCV-infection prevalence <10% (145,146). Supplemental testing with a more specific assay (i.e., RIBA™) of a specimen with a positive anti-HCV result by EIA prevents reporting of false-positive results, particularly in settings where asymptomatic persons are being tested. Results of seroprevalence studies among chronic hemodialysis patients have indicated that 57%–100% of EIA positive results were RIBA™ positive (124,126,128,133,135,147–152), and 53%–100% were HCV RNA positive by reverse transcriptase polymerase chain reaction (RT-PCR) testing (117,127,129,134,135).

Nucleic Acid Detection. The diagnosis of HCV infection also can be made by qualitatively detecting HCV RNA using gene amplification techniques (e.g., RT-PCR) (116). HCV RNA can be detected in serum or plasma within 1–2 weeks after exposure and weeks before onset of ALT elevations or the appearance of anti-HCV. In rare instances, detection of HCV RNA might be the only evidence of HCV infection. Although a median of 3.4% (range: 0%–28%) of chronic hemodialysis patients who tested anti-HCV negative were HCV RNA positive, this might be an overestimate because follow-up samples to detect possible antibody seroconversions were not obtained on these patients (117,118,126–128,130,131,133,134,148–154).

Although not FDA-approved, RT-PCR assays for HCV infection are used commonly in clinical practice and are commercially available. Most RT-PCR assays have a lower limit of detection of 100–1,000 viral genome copies per mL. With adequate optimization of RT-PCR assays, 75%–85% of persons who are positive for anti-HCV and >95% of persons with acute or chronic hepatitis C will test positive for HCV RNA. Some HCV-infected persons might be only intermittently HCV RNA positive, particularly those with acute hepatitis C or with end-stage liver disease caused by hepatitis C. To minimize false-negative results, blood samples collected for RT-PCR should not contain heparin, and serum must be separated from cellular components within 2–4 hours after collection and preferably stored frozen at -20 C or -70 C (155). If shipping is required, frozen samples should be protected from thawing. Because of assay variability,

rigorous quality assurance and control should be in place in clinical laboratories performing this assay, and proficiency testing is recommended.

Quantitative assays for measuring the concentration (i.e., titer) of HCV RNA have been developed and are available from commercial laboratories (156). These assays also are not FDA-approved and are less sensitive than qualitative RT-PCR assays (157). Quantitative assays should not be used as a primary test to confirm or exclude the diagnosis of HCV infection or to monitor the endpoint of treatment, and sequential measurement of HCV RNA levels has not proven useful in managing patients with hepatitis C.

Other Bloodborne Viruses

Hepatitis Delta Virus Infection

Delta hepatitis is caused by the hepatitis delta virus (HDV), a defective virus that causes infection only in persons with active HBV infection. The prevalence of HDV infection is low in the United States, with rates of <1% among HBsAg-positive persons in the general population and $\geq 10\%$ among HBsAg-positive persons with repeated percutaneous exposures (e.g., injecting-drug users, persons with hemophilia) (158). Areas of the world with high endemic rates of HDV infection include southern Italy, parts of Africa, and the Amazon Basin.

Few data exist on the prevalence of HDV infection among chronic hemodialysis patients, and only one transmission of HDV between such patients has been reported in the United States (159). In this episode, transmission occurred from a patient who was chronically infected with HBV and HDV to an HBsAg-positive patient after a massive bleeding incident; both patients received dialysis at the same station.

HDV infection occurs either as a co-infection with HBV or as a superinfection in a person with chronic HBV infection. Co-infection usually resolves, but superinfection frequently results in chronic HDV infection and severe disease. High mortality rates are associated with both types of infection. A serologic test that measures total antibody to HDV (anti-HDV) is commercially available.

Human Immunodeficiency Virus Infection

During 1985–1999, the percentage of U.S. hemodialysis centers that reported providing chronic hemodialysis for patients with HIV infection increased from 11% to 39%, and the proportion of hemodialysis patients with known HIV infection increased from 0.3% to 1.4% (18) (CDC, unpublished data, 2001).

HIV is transmitted by blood and other body fluids that contain blood. No patient-to-patient transmission of HIV has been reported in U.S. hemodialysis centers. However, such transmission has been reported in other countries; in one case, HIV transmission was attributed to mixing of reused access needles and inadequate disinfection of equipment (160).

HIV infection is usually diagnosed with assays that measure antibody to HIV, and a repeatedly positive EIA test should be confirmed by Western blot or another confirmatory test. Antiretroviral therapies for HIV-infected hemodialysis patients are commonly used and appear to be improving survival rates among this population. However, hepatotoxicity associated with certain protease inhibitors might limit the use of these drugs, especially in patients with underlying liver dysfunction (161).

Bacterial Infections

Epidemiology

Disease Burden. The annual mortality rate among hemodialysis patients is 23%, and infections are the second most common cause, accounting for 15% of deaths (1). Septicemia (10.9% of all deaths) is the most common infectious cause of mortality. In various studies evaluating rates of bacterial infections in hemodialysis outpatients, bacteremia occurred in 0.63%–1.7% of patients per month and vascular access infections (with or without bacteremia) in 1.3%–7.2% of patients per month (162–170). National surveillance data indicated that 4%–5% of patients received intravenous vancomycin during a 1-month period (and additional patients received other antimicrobials) (18). Although data on vancomycin use can be used to derive an estimate of the prevalence of suspected infections, the proportion of patients receiving antimicrobials who would fit a formal case definition for bacterial infection is unknown.

Infection Sites. In a study of 27 French hemodialysis centers, 28% of 230 infections in hemodialysis patients involved the vascular access, whereas 25% involved the lung, 23% the urinary tract, 9% the skin and soft tissues, and 15% other or unknown sites (165). Thirty-three percent of infections involved either the vascular access site or were bacteremias of unknown origin, many of which might have been caused by occult access infections. Thus, the vascular access site was the most common site for infection, but accounted for only one-third of infections. However, access site infections are particularly important because they can cause disseminated bacteremia or loss of the vascular access.

Vascular Access Infections. Vascular access infections are caused (in descending order of frequency) by *S. aureus*, coagulase-negative staphylococci (CNS), gram-negative bacilli, nonstaphylococcal gram-positive cocci (including enterococci), and fungi (171). The proportion of infections caused by CNS is higher among patients dialyzed through catheters than among patients dialyzed through fistulas or grafts.

The primary risk factor for access infection is access type, with catheters having the highest risk for infection, grafts intermediate, and native arteriovenous (AV) fistulas the lowest (168). Other potential risk factors for vascular access infections include a) location of the access in the lower extremity; b) recent access surgery; c) trauma, hematoma, dermatitis, or scratching over the access site; d) poor patient hygiene; e) poor needle insertion technique; f) older age; g) diabetes; h) immunosuppression; and i) iron overload (164,167,172–175).

Transmission. Bacterial pathogens causing infection can be either exogenous (i.e., acquired from contaminated dialysis fluids or equipment) or endogenous (i.e., caused by invasion of bacteria present in or on the patient). Exogenous pathogens have caused numerous outbreaks, most of which resulted from inadequate dialyzer reprocessing procedures (e.g., contaminated water or inadequate disinfectant) or inadequate treatment of municipal water for use in dialysis. During 1995–1997, four outbreaks were traced to contamination of the waste drain port on one type of dialysis machine (176). Recommendations to prevent such outbreaks are published elsewhere (171).

Contaminated medication vials also are a potential source of bacterial infection for patients. In 1999, an outbreak of *Serratia liquefaciens* bloodstream infections and pyrogenic reactions among hemodialysis patients was traced to contamination of vials of erythropoietin. These vials, which were intended for single use, were contaminated by

repeated puncture to obtain additional doses and by pooling of residual medication into a common vial (177).

Endogenous pathogens first colonize the patient and later cause infection. Colonization means that microorganisms have become resident in or on the body (e.g., in the nares or stool); a culture from the site is positive, but no symptoms or signs of infection exist. Colonization with potentially pathogenic microorganisms, often unknown to staff members, is common in patients with frequent exposure to hospitals and other health-care settings. Colonization most often occurs when microorganisms are transmitted from a colonized or infected source patient to another patient on the hands of health-care workers who do not comply with infection control precautions. Less commonly, contamination of environmental surfaces (e.g., bed rails, countertops) plays a role (178).

Infection occurs when microorganisms invade the body, damaging tissue and causing signs or symptoms of infection, and is aided by invasive devices (e.g., the hemodialysis vascular access). Evidence exists that when prevalence of colonization in a population is less frequent, infection in that population will also be less frequent, and infection control recommendations for hemodialysis units are designed to prevent colonization (179). Additional measures designed to prevent infection from colonizing organisms (e.g., using aseptic technique during vascular access) are presented elsewhere (180).

Antimicrobial Resistance

Antimicrobial-resistant bacteria are more common in patients with severe illness, who often have had multiple hospitalizations or surgical procedures, and in those who have received prolonged courses of antimicrobial agents. In health-care settings, including hemodialysis centers, such patients can serve as a source for transmission.

Clinically important drug-resistant bacteria that commonly cause health-care-associated infections include MRSA, methicillin-resistant CNS, VRE, and multidrug-resistant gram negative rods, including strains of *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, and *Acinetobacter* species, some of which are resistant to all available antimicrobials. In addition, strains of *S. aureus* with intermediate resistance to vancomycin and other glycopeptide antibiotics have recently been reported; these strains are called vancomycin-intermediate *S. aureus* (VISA) or glycopeptide-intermediate *S. aureus* (GISA) (181,182). Intermediate resistance to vancomycin is reported even more frequently among CNS (183,184).

Hemodialysis patients have played a prominent role in the epidemic of vancomycin resistance. In 1988, a renal unit in London, England, reported one of the first cases of VRE (185). In three studies, 12%–22% of hospitalized patients infected or colonized with VRE were receiving hemodialysis (178,186,187). Furthermore, three of the first five patients identified with VISA (or GISA) were on chronic hemodialysis, and one had received acute dialysis (182).

Prevalence of VRE has increased rapidly at U.S. hospitals; among intensive care unit patients with nosocomial infections reported to the National Nosocomial Infections Surveillance (NNIS) system, the percentage of enterococcal isolates resistant to vancomycin increased from 0.5% in 1989 to 25.2% in 1999 (23) (CDC, unpublished data, 2000). This increase is attributable to patient-to-patient transmission in health-care settings and transmission of resistant genes among previously susceptible enterococci. Once vancomycin resistance has been transferred to a patient, antimicrobials select for resistant organisms, causing them to increase in number relative to suscep-

tible organisms. Prevalence of VRE colonization among patients varies in different health-care settings; in hemodialysis centers, the reported prevalence in stool samples ranged from 1% to 9% (188,189). In one center with a prevalence of 9%, three patients developed VRE infections in 1 year (188).

Vancomycin Use

Dialysis patients have played a prominent role in the epidemic of vancomycin resistance because this drug is used commonly in these patients, in part because vancomycin can be conveniently administered to patients when they come in for hemodialysis treatments. However, two studies indicate that cefazolin, a first-generation cephalosporin, could be substituted for vancomycin in many patients (190,191). One of these studies reported that many pathogens causing infections in hemodialysis patients are susceptible to cefazolin (190), and both studies reported therapeutic cefazolin blood levels 48–72 hours after dosing, making in-center administration three times a week after dialysis feasible.

Equipment, Supplies, and Environmental Surfaces

The hemodialysis machine and its components also can be vehicles for patient-to-patient transmission of bloodborne viruses and pathogenic bacteria (24,192). The external surfaces of the machine are the most likely sources for contamination. These include not only frequently touched surfaces (e.g., the control panel), but also attached waste containers used during the priming of the dialyzers, blood tubing draped or clipped to waste containers, and items placed on tops of machines for convenience (e.g., dialyzer caps and medication vials).

Sterilization, Disinfection, and Cleaning

A sterilization procedure kills all microorganisms, including highly resistant bacterial spores (24). Sterilization procedures are most commonly accomplished by steam or ethylene oxide gas. For products that are heat sensitive, an FDA-cleared liquid chemical sterilant can be used with a long exposure time (i.e., 3–10 hours).

High-level disinfection kills all viruses and bacteria, but not high numbers of bacterial spores. High-level disinfection can be accomplished by heat pasteurization or, more commonly, by an FDA-cleared chemical sterilant, with an exposure time of 12–45 minutes. Sterilants and high-level disinfectants are designed to be used on medical devices, not environmental surfaces. Intermediate-level disinfection kills bacteria and most viruses and is accomplished by using a tuberculocidal “hospital disinfectant” (a term used by the U.S. Environmental Protection Agency [EPA] in registering germicides) or a 1:100 dilution of bleach (300–600 mg/L free chlorine). Low-level disinfection kills most bacteria and is accomplished by using general purpose disinfectants. Intermediate and low-level disinfectants are designed to be used on environmental surfaces; they also can be used on noncritical medical devices, depending on the design and labeling claim.

Cleaning eliminates dirt and some bacteria and viruses and is accomplished by using a detergent or detergent germicide. Antiseptics (e.g., formulations with povidone-iodine, hexachlorophene, or chlorhexidene) are designed for use on skin and tissue and should not be used on medical equipment or environmental surfaces.

Regardless of the procedure used, cleaning with a germicidal detergent before disinfection (or sterilization) is essential to remove organic material (e.g., blood, mucous, or feces), dirt, or debris. The presence of such material protects microorganisms from the sterilization or disinfection process by physically blocking or inactivating the disinfectant or sterilant.

The choice of what procedure or which chemical germicide to use for medical devices, instruments, and environmental surfaces depends on several factors, including the need to maintain the structural integrity and function of the item and how the item will be used. Three general categories of use for medical items are recognized, each of which require different levels of sterilization or disinfection (193). These categories are a) critical, which includes items introduced directly into the bloodstream or normally sterile areas of the body (e.g., needles, catheters, hemodialyzers, blood tubing); b) semicritical, which includes equipment that comes in contact with intact mucous membranes (e.g., fiberoptic endoscopes, glass thermometers); and c) noncritical, which includes equipment that touches only intact skin (e.g., blood pressure cuffs). Semicritical items are not generally used in dialysis units.

Internal Pathways of Hemodialysis Machines. In single-pass hemodialysis machines, the internal fluid pathways are not subject to contamination with blood. If a dialyzer leak occurs, dialysis fluid might become contaminated with blood, but this contaminated fluid is discarded through a drain and does not return to the dialysis machine to contaminate predialyzer surfaces. For dialysis machines that use a dialysate recirculating system (e.g., some ultrafiltration control machines and those that regenerate the dialysate), a blood leak in a dialyzer could contaminate the internal pathways of the machine, which could in turn contaminate the dialysis fluid of subsequent patients (192). However, procedures normally practiced after each use (i.e., draining the dialysis fluid and rinsing and disinfecting the machine) will reduce the level of contamination to below infectious levels. In addition, an intact dialyzer membrane will not allow passage of bacteria or viruses (24).

Pressure transducer filter protectors are used primarily to prevent contamination and preserve the functioning of the pressure monitoring (i.e., arterial, venous, or both) components of the hemodialysis machine. Hemodialysis machines usually have both external (typically supplied with the blood tubing set) and internal protectors, with the internal protector serving as a backup in case the external transducer protector fails. Failure to use an external protector or to replace the protector when it becomes contaminated (i.e., wetted with saline or blood) can result in contamination of the internal transducer protector, which in turn could allow transmission of bloodborne pathogens (24). However, no epidemiologic evidence exists that contamination of the internal transducer protector caused by failure of the external transducer protector has led to either mixing of blood or the transmission of bloodborne agents.

Dialyzer Reprocessing. Approximately 80% of U.S. chronic hemodialysis centers reprocess (i.e., reuse) dialyzers for the same patient (18), and guidelines for reprocessing have been published elsewhere (see Suggested Readings). Although outbreaks of bacterial infections and pyrogenic reactions have occurred because of inadequate reprocessing procedures and failure to maintain standards for water quality, reuse has not been associated with transmission of bloodborne viruses. Any theoretical risk for HBV transmission from reuse of dialyzers would primarily affect staff members who handle these dialyzers. Although no increase in HBV (or HCV) infection among staff

members who work in such centers has been reported, many centers do not reuse dialyzers from HBsAg-positive patients (24).

Infection Control Precautions for Outpatient Hemodialysis Settings Compared with Inpatient Hospital Settings

Contact transmission is the most important route by which pathogens are transmitted in health-care settings, including hemodialysis units. Contact transmission occurs most commonly when microorganisms from a patient are transferred to the hands of a health-care worker who does not comply with infection control precautions, then touches another patient. Less commonly, environmental surfaces (e.g., bed rails, countertops) become contaminated and serve as an intermediate reservoir for pathogens; transmission can occur when a worker touches the surface then touches a patient or when a patient touches the surface.

In the hemodialysis setting, contact transmission plays a major role in transmission of bloodborne pathogens. If a health-care worker's hands become contaminated with virus-infected blood from one patient, the worker can transfer the virus to a second patient's skin or blood line access port, and the virus can be inoculated into that patient when the skin or access port is punctured with a needle.

Contact transmission can be prevented by hand hygiene (i.e., hand washing or use of a waterless hand rub), glove use, and disinfection of environmental surfaces. Of these, hand hygiene is the most important. In addition, nonsterile disposable gloves provide a protective barrier for workers' hands, preventing them from becoming soiled or contaminated, and reduce the likelihood that microorganisms present on the hands of personnel will be transmitted to patients. However, even with glove use, hand washing is needed because pathogens deposited on the outer surface of gloves can be detected on hands after glove removal, possibly because of holes or defects in the gloves, leakage at the wrist, or contamination of hands during glove removal (194).

Standard Precautions are the system of infection control precautions recommended for the inpatient hospital setting (195). Standard Precautions are used on all patients and include use of gloves, gown, or mask whenever needed to prevent contact of the health-care worker with blood, secretions, excretions, or contaminated items.

In addition to Standard Precautions, more stringent precautions are recommended for hemodialysis units because of the increased potential for contamination with blood and pathogenic microorganisms (see Infection Control Practices Recommended for Hemodialysis Units). For example, infection control practices for hemodialysis units restrict the use of common supplies, instruments, medications, and medication trays and prohibit the use of a common medication cart.

For certain patients, including those infected or colonized with MRSA or VRE, contact precautions are used in the inpatient hospital setting. Contact precautions include a) placing the patient in a single room or with another patient infected or colonized with the same organism; b) using gloves whenever entering the patient's room; and c) using a gown when entering the patient's room if the potential exists for the worker's clothing to have substantial contact with the patient, environmental surfaces, or items in the patient's room. Workers also should wear a gown if the patient has diarrhea, an ileostomy, a colostomy, or wound drainage not contained by a dressing.

However, contact precautions are not recommended in hemodialysis units for patients infected or colonized with pathogenic bacteria for several reasons. First, although

contact transmission of pathogenic bacteria is well-documented in hospitals, similar transmission has not been well-documented in hemodialysis centers. Transmission might not be apparent in dialysis centers, possibly because it occurs less frequently than in acute-care hospitals or results in undetected colonization rather than overt infection. Also, because dialysis patients are frequently hospitalized, determining whether transmission occurred in the inpatient or outpatient setting is difficult. Second, contamination of the patient's skin, bedclothes, and environmental surfaces with pathogenic bacteria is likely to be more common in hospital settings (where patients spend 24 hours a day) than in outpatient hemodialysis centers (where patients spend approximately 10 hours a week). Third, the routine use of infection control practices recommended for hemodialysis units, which are more stringent than the Standard Precautions routinely used in hospitals, should prevent transmission by the contact route.

RECOMMENDATIONS

Rationale

Preventing transmission among chronic hemodialysis patients of bloodborne viruses and pathogenic bacteria from both recognized and unrecognized sources of infection requires implementation of a comprehensive infection control program. The components of such a program include infection control practices specifically designed for the hemodialysis setting, including routine serologic testing and immunization, surveillance, and training and education (Box).

The infection control practices recommended for hemodialysis units will reduce opportunities for patient-to-patient transmission of infectious agents, directly or indirectly via contaminated devices, equipment and supplies, environmental surfaces, or hands of personnel. These practices should be carried out routinely for all patients in the chronic hemodialysis setting because of the increased potential for blood contamination during hemodialysis and because many patients are colonized or infected with pathogenic bacteria. Such practices include additional measures to prevent HBV transmission because of the high titer of HBV and its ability to survive on environmental surfaces. For patients at increased risk for transmission of pathogenic bacteria, includ-

BOX. Components of a comprehensive infection control program to prevent transmission of infections among chronic hemodialysis patients

- **Infection control practices for hemodialysis units.**
 - Infection control precautions specifically designed to prevent transmission of bloodborne viruses and pathogenic bacteria among patients.
 - Routine serologic testing for hepatitis B virus and hepatitis C virus infections.
 - Vaccination of susceptible patients against hepatitis B.
 - Isolation of patients who test positive for hepatitis B surface antigen.
- **Surveillance for infections and other adverse events.**
- **Infection control training and education.**

ing antimicrobial-resistant strains, additional precautions also might be necessary in some circumstances. Furthermore, surveillance for infections and other adverse events is required to monitor the effectiveness of infection control practices, as well as training and education of both staff members and patients to ensure that appropriate infection control behaviors and techniques are carried out.

Infection Control Practices for Hemodialysis Units

In each chronic hemodialysis unit, policies and practices should be reviewed and updated to ensure that infection control practices recommended for hemodialysis units are implemented and rigorously followed (see Recommended Infection Control Practices for Hemodialysis Units at a Glance). Intensive efforts must be made to educate new staff members and reeducate existing staff members regarding these practices.

Infection Control Precautions for All Patients

During the process of hemodialysis, exposure to blood and potentially contaminated items can be routinely anticipated; thus, gloves are required whenever caring for a patient or touching the patient's equipment. To facilitate glove use, a supply of clean nonsterile gloves and a glove discard container should be placed near each dialysis station. Hands always should be washed after gloves are removed and between patient contacts, as well as after touching blood, body fluids, secretions, excretions, and contaminated items. A sufficient number of sinks with warm water and soap should be available to facilitate hand washing. If hands are not visibly soiled, use of a waterless antiseptic hand rub can be substituted for hand washing.

Any item taken to a patient's dialysis station could become contaminated with blood and other body fluids and serve as a vehicle of transmission to other patients either directly or by contamination of the hands of personnel. Therefore, items taken to a patient's dialysis station, including those placed on top of dialysis machines, should either be disposed of, dedicated for use only on a single patient, or cleaned and disinfected before being returned to a common clean area or used for other patients. Unused medications or supplies (e.g., syringes, alcohol swabs) taken to the patient's station should not be returned to a common clean area or used on other patients.

Additional measures to prevent contamination of clean or sterile items include a) preparing medications in a room or area separated from the patient treatment area and designated only for medications; b) not handling or storing contaminated (i.e., used) supplies, equipment, blood samples, or biohazard containers in areas where medications and clean (i.e., unused) equipment and supplies are handled; and c) delivering medications separately to each patient. Common carts should not be used within the patient treatment area to prepare or distribute medications. If trays are used to distribute medications, clean them before using for a different patient.

Intravenous medication vials labeled for single use, including erythropoetin, should not be punctured more than once (196,197). Once a needle has entered a vial labeled for single use, the sterility of the product can no longer be guaranteed. Residual medication from two or more vials should not be pooled into a single vial.

If a common supply cart is used to store clean supplies in the patient treatment area, this cart should remain in a designated area at a sufficient distance from patient stations to avoid contamination with blood. Such carts should not be moved between stations to distribute supplies.

Infection Control Precautions for All Patients

- Wear disposable gloves when caring for the patient or touching the patient’s equipment at the dialysis station; remove gloves and wash hands between each patient or station.
- Items taken into the dialysis station should either be disposed of, dedicated for use only on a single patient, or cleaned and disinfected before being taken to a common clean area or used on another patient.
 - Nondisposable items that cannot be cleaned and disinfected (e.g., adhesive tape, cloth-covered blood pressure cuffs) should be dedicated for use only on a single patient.
 - Unused medications (including multiple dose vials containing diluents) or supplies (e.g., syringes, alcohol swabs) taken to the patient’s station should be used only for that patient and should not be returned to a common clean area or used on other patients.
- When multiple dose medication vials are used (including vials containing diluents), prepare individual patient doses in a clean (centralized) area away from dialysis stations and deliver separately to each patient. Do not carry multiple dose medication vials from station to station.
- Do not use common medication carts to deliver medications to patients. Do not carry medication vials, syringes, alcohol swabs, or supplies in pockets. If trays are used to deliver medications to individual patients, they must be cleaned between patients.

Schedule for Routine Testing for Hepatitis B Virus (HBV) and Hepatitis C Virus (HCV) Infections

Patient Status	On Admission	Monthly	Semiannual	Annual
All patients	HBsAg,* Anti-HBc* (total), Anti-HBs,* Anti-HCV, ALT†			
HBV-susceptible, including nonresponders to vaccine		HBsAg		
Anti-HBs positive (≥10 mIU/mL), anti-HBc negative				Anti-HBs
Anti-HBs and anti-HBc positive		No additional HBV testing needed		
Anti-HCV negative		ALT	Anti-HCV	

* Results of HBV testing should be known before the patient begins dialysis.
 † HBsAg=hepatitis B surface antigen; Anti-HBc=antibody to hepatitis B core antigen; Anti-HBs=antibody to hepatitis B surface antigen; Anti-HCV=antibody to hepatitis C virus; ALT=alanine aminotransferase.

(Continued on page 21)

- Clean areas should be clearly designated for the preparation, handling, and storage of medications and unused supplies and equipment. Clean areas should be clearly separated from contaminated areas where used supplies and equipment are handled. Do not handle and store medications or clean supplies in the same or an adjacent area to where used equipment or blood samples are handled.
- Use external venous and arterial pressure transducer filters/protectors for each patient treatment to prevent blood contamination of the dialysis machines' pressure monitors. Change filters/protectors between each patient treatment, and do not reuse them. Internal transducer filters do not need to be changed routinely between patients.
- Clean and disinfect the dialysis station (e.g., chairs, beds, tables, machines) between patients.
 - Give special attention to cleaning control panels on the dialysis machines and other surfaces that are frequently touched and potentially contaminated with patients' blood.
 - Discard all fluid and clean and disinfect all surfaces and containers associated with the prime waste (including buckets attached to the machines).
- For dialyzers and blood tubing that will be reprocessed, cap dialyzer ports and clamp tubing. Place all used dialyzers and tubing in leakproof containers for transport from station to reprocessing or disposal area.

Hepatitis B Vaccination

- Vaccinate all susceptible patients against hepatitis B.
 - Test for anti-HBs 1-2 months after last dose.
 - If anti-HBs is <10 mIU/mL, consider patient susceptible, revaccinate with an additional three doses, and retest for anti-HBs.
 - If anti-HBs is ≥ 10 mIU/mL, consider patient immune, and retest annually.
 - Give booster dose of vaccine if anti-HBs declines to <10 mIU/mL and continue to retest annually.
-

Management of HBsAg-Positive Patients

- Follow infection control practices for hemodialysis units for all patients.
 - Dialyze HBsAg-positive patients in a separate room using separate machines, equipment, instruments, and supplies.
 - Staff members caring for HBsAg-positive patients should not care for HBV-susceptible patients at the same time (e.g., during the same shift or during patient changeover).
-

Staff members should wear gowns, face shields, eye wear, or masks to protect themselves and prevent soiling of clothing when performing procedures during which spurt-ing or spattering of blood might occur (e.g., during initiation and termination of dialysis, cleaning of dialyzers, and centrifugation of blood). Such protective clothing or gear should be changed if it becomes soiled with blood, body fluids, secretions, or excre-tions. Staff members should not eat, drink, or smoke in the dialysis treatment area or in the laboratory. However, patients can be served meals or eat food brought from home at their dialysis station. The glasses, dishes, and other utensils should be cleaned in the usual manner; no special care of these items is needed.

Cleaning and Disinfection. Establish written protocols for cleaning and disinfecting surfaces and equipment in the dialysis unit, including careful mechanical cleaning be-fore any disinfection process (Table 2). If the manufacturer has provided instructions on sterilization or disinfection of the item, these instructions should be followed. For each chemical sterilant and disinfectant, follow the manufacturer's instructions regarding use, including appropriate dilution and contact time.

After each patient treatment, clean environmental surfaces at the dialysis station, including the dialysis bed or chair, countertops, and external surfaces of the dialysis machine, including containers associated with the prime waste. Use any soap, deter-gent, or detergent germicide. Between uses of medical equipment (e.g., scissors, he-mostats, clamps, stethoscopes, blood pressure cuffs), clean and apply a hospital disinfectant (i.e., low-level disinfection); if the item is visibly contaminated with blood, use a tuberculocidal disinfectant (i.e., intermediate-level disinfection).

For a blood spill, immediately clean the area with a cloth soaked with a tubercu-locidal disinfectant or a 1:100 dilution of household bleach (300–600 mg/L free chlorine) (i.e., intermediate-level disinfection). The staff member doing the cleaning should wear gloves, and the cloth should be placed in a bucket or other leakproof container. After all visible blood is cleaned, use a new cloth or towel to apply disinfectant a second time.

Published methods should be used to clean and disinfect the water treatment and distribution system and the internal circuits of the dialysis machine, as well as to repro-

TABLE 2. Disinfection procedures recommended for commonly used items or surfaces in hemodialysis units

Item or Surface	Low-Level Disinfection*	Intermediate-Level Disinfection*
Gross blood spills or items contaminated with visible blood		X
Hemodialyzer port caps		X
Interior pathways of dialysis machine		X
Water treatment and distribution system	X	X [†]
Scissors, hemostats, clamps, blood pressure cuffs, stethoscopes	X	X [§]
Environmental surfaces, including exterior surfaces of hemodialysis machines	X	

* Careful mechanical cleaning to remove debris should always be done before disinfection.

[†] Water treatment and distribution systems of dialysis fluid concentrates require more extensive disinfection if significant biofilm is present within the system.

[§] If item is visibly contaminated with blood, use a tuberculocidal disinfectant.

cess dialyzers for reuse (see Suggested Readings). These methods are designed to control bacterial contamination, but will also eliminate bloodborne viruses. For single-pass machines, perform rinsing and disinfection procedures at the beginning or end of the day. For batch recirculating machines, drain, rinse, and disinfect after each use. Follow the same methods for cleaning and disinfection if a blood leak has occurred, regardless of the type of dialysis machine used. Routine bacteriologic assays of water and dialysis fluids should be performed according to the recommendations of the Association for the Advancement of Medical Instrumentation (see Suggested Readings).

Venous pressure transducer protectors should be used to cover pressure monitors and should be changed between patients, not reused. If the external transducer protector becomes wet, replace immediately and inspect the protector. If fluid is visible on the side of the transducer protector that faces the machine, have qualified personnel open the machine after the treatment is completed and check for contamination. This includes inspection for possible blood contamination of the internal pressure tubing set and pressure sensing port. If contamination has occurred, the machine must be taken out of service and disinfected using either 1:100 dilution of bleach (300–600 mg/L free chlorine) or a commercially available, EPA-registered tuberculocidal germicide before reuse. Frequent blood line pressure alarms or frequent adjusting of blood drip chamber levels can be an indicator of this problem. Taken separately, these incidents could be characterized as isolated malfunctions. However, the potential public health significance of the total number of incidents nationwide make it imperative that all incidents of equipment contamination be reported immediately to the FDA (800-FDA-1088).

Housekeeping staff members in the dialysis facility should promptly remove soil and potentially infectious waste and maintain an environment that enhances patient care. All disposable items should be placed in bags thick enough to prevent leakage. Wastes generated by the hemodialysis facility might be contaminated with blood and should be considered infectious and handled accordingly. These solid medical wastes should be disposed of properly in an incinerator or sanitary landfill, according to local and state regulations governing medical waste disposal.

Hemodialysis in Acute-Care Settings. For patients with acute renal failure who receive hemodialysis in acute-care settings, Standard Precautions as applied in all health-care settings are sufficient to prevent transmission of bloodborne viruses. However, when chronic hemodialysis patients receive maintenance hemodialysis while hospitalized, infection control precautions specifically designed for chronic hemodialysis units (see Recommended Practices at a Glance) should be applied to these patients. If both acute and chronic renal failure patients receive hemodialysis in the same unit, these infection control precautions should be applied to all patients.

Regardless of where in the acute-care setting chronic hemodialysis patients receive dialysis, the HBsAg status of all such patients should be ascertained at the time of admission to the hospital, by either a written report from the referring center (including the most recent date testing was performed) or by a serologic test. The HBV serologic status should be prominently placed in patients' hospital records, and all health-care personnel assigned to these patients, as well as the infection control practitioner, should be aware of the patients' serologic status. While hospitalized, HBsAg-positive chronic hemodialysis patients should undergo dialysis in a separate room and use separate machines, equipment, instruments, supplies, and medications designated only for HBsAg-positive patients (see Prevention and Management of HBV Infection). While HBsAg-positive patients are receiving dialysis, staff members who are caring for them should not care for susceptible patients.

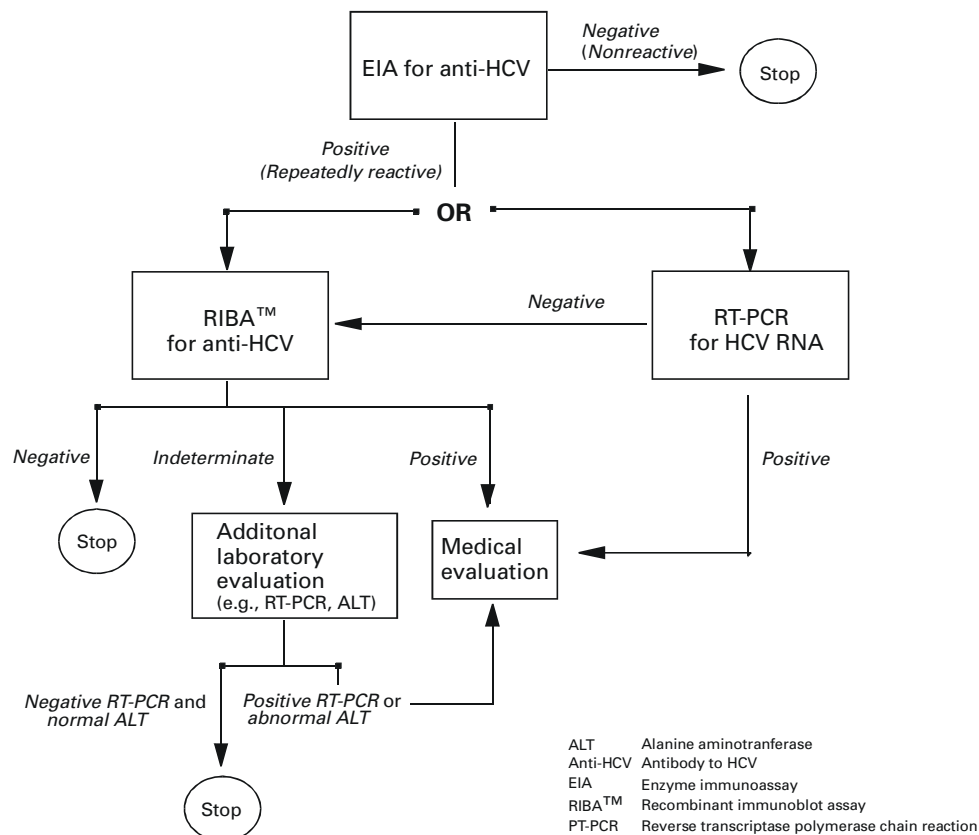
Routine Serologic Testing

Chronic Hemodialysis Patients. Routinely test all chronic hemodialysis patients for HBV and HCV infection (see Recommended Practices at a Glance), promptly review results, and ensure that patients are managed appropriately based on their testing results (see later recommendations for each virus). Communicate test results (positive and negative) to other units or hospitals when patients are transferred for care. Routine testing for HDV or HIV infection for purposes of infection control is not recommended.

The HBV serologic status (i.e., HBsAg, total anti-HBc, and anti-HBs) of all patients should be known before admission to the hemodialysis unit. For patients transferred from another unit, test results should be obtained before the patients' transfer. If a patient's HBV serologic status is not known at the time of admission, testing should be completed within 7 days. The hemodialysis unit should ensure that the laboratory performing the testing for anti-HBs can define a 10 mIU/mL concentration to determine protective levels of antibody.

Routine HCV testing should include use of both an EIA to test for anti-HCV and supplemental or confirmatory testing with an additional, more specific assay (Figure). Use of RT-PCR for HCV RNA as the primary test for routine screening is not recommended because few HCV infections will be identified in anti-HCV negative patients.

FIGURE. Algorithm for hepatitis C virus (HCV) infection testing among persons who are asymptomatic



Source: CDC. Recommendations for prevention and control of hepatitis C virus (HCV) infection and HCV-related chronic disease. MMWR 1998;47(No. RR-19):27.

However, if ALT levels are persistently abnormal in patients who are anti-HCV negative in the absence of another etiology, testing for HCV RNA should be considered (for proper specimen collection and handling, see Hepatitis C Virus Infection, Screening and Diagnostic Tests).

Hemodialysis Staff Members. Previously, testing for HBV infection was recommended for all staff members at the time of employment and for susceptible staff members at routine intervals thereafter (198); however, such testing is no longer considered necessary. The risk for HBV infection among hemodialysis staff members is no greater than that for other health-care workers. Thus, routine testing of staff members is not recommended except when required to document response to hepatitis B vaccination (see Postvaccination Testing and Revaccination of Nonresponders). Routine testing of staff members for HCV, HDV, or HIV infection is not recommended.

Hepatitis B Vaccination

Vaccine Schedule and Dose. Hepatitis B vaccination is recommended for all susceptible chronic hemodialysis patients and for all staff members (Table 3). Vaccination is recommended for pre-end-stage renal disease patients before they become dialysis dependent and for peritoneal and home dialysis patients because they might require in-center hemodialysis. Hepatitis B vaccine should be administered by the intramuscular route and only in the deltoid muscle for adults and children. Intradermal or subcutaneous administration of hepatitis B vaccine is not recommended.

If an adult patient begins the vaccine series with a standard dose before beginning hemodialysis treatment, then moves to hemodialysis treatment before completing the series, complete the series using the higher dose recommended for hemodialysis patients (Table 3). No specific recommendations have been made for higher doses for pediatric hemodialysis patients. If a lower than recommended vaccine dose is administered to either adults or children, the dose should be repeated.

TABLE 3. Doses and schedules of licensed hepatitis B vaccines for hemodialysis patients and staff members

Group	Recombivax HB™*			Engerix-B®†		
	Dose	Volume	Schedule	Dose	Volume	Schedule
Patients aged ≥20 years						
Predialysis‡	10 µg	1.0 mL	0, 1, and 6 months	20 µg	1.0 mL	0, 1, and 6 months
Dialysis-dependent	40 µg	1.0 mL†	0, 1, and 6 months	40 µg	2–1.0 mL doses at one site	0, 1, 2, and 6 months
Patients aged <20 years**	5 µg	0.5 mL	0, 1, and 6 months	10 µg	0.5 mL	0, 1, and 6 months
Staff members aged ≥20 years	10 µg	1.0 mL	0, 1, and 6 months	20 µg	1.0 mL	0, 1, and 6 months

* Merck & Company, Inc., West Point, Pennsylvania.

† SmithKline Beecham Biologicals, Philadelphia, Pennsylvania.

‡ Immunogenicity might depend on degree of renal insufficiency.

† Special formulation.

** Doses for all persons aged <20 years approved by the U.S. Food and Drug Administration; for hemodialysis patients, higher doses might be more immunogenic.

Note: All doses should be administered in the deltoid by the intramuscular route.

If the vaccination series is interrupted after the first dose, the second dose should be administered as soon as possible. For the three-dose primary vaccine series, the second and third doses should be separated by an interval of at least 2 months; if only the third dose is delayed, that dose should be administered when convenient. When hepatitis B vaccine has been administered at the same time as other vaccines, no interference with the antibody response of the other vaccines has been demonstrated.

Postvaccination Testing and Revaccination of Nonresponders. Test all vaccinees for anti-HBs 1–2 months after the last primary vaccine dose, to determine their response to the vaccine (adequate response is defined as ≥ 10 mIU/mL). Patients and staff members who do not respond to the primary vaccine series should be revaccinated with three additional doses and retested for response. No additional doses of vaccine are warranted for those who do not respond to the second series.

Evaluate staff members who do not respond to revaccination to determine if they are HBsAg positive (199). Persons who are HBsAg positive should be counseled accordingly (e.g., need for medical evaluation, vaccination of sexual and household contacts). Primary nonresponders to vaccination who are HBsAg negative should be considered susceptible to HBV infection and counseled regarding precautions to prevent HBV infection and the need to obtain postexposure prophylaxis with hepatitis B immune globulin for any known or probable percutaneous or mucosal exposure to HBsAg-positive blood (199).

Follow-Up of Vaccine Responders. Retest patients who respond to the vaccine annually for anti-HBs. If anti-HBs declines to < 10 mIU/mL, administer a booster dose of hepatitis B vaccine and continue to retest annually. Retesting immediately after the booster dose is not necessary. For staff members who respond to the vaccine, booster doses of vaccine are not necessary, and periodic serologic testing to monitor antibody concentrations is not recommended (199).

Patients with a History of Vaccination. Routine childhood vaccination against hepatitis B has been recommended since 1991 and routine adolescent vaccination since 1995 (89,198). Thus, many persons who develop end-stage renal failure will have a history of vaccination against hepatitis B. These persons should have responded to the vaccine when their immune status was normal, but if their anti-HBs levels are < 10 mIU/mL when they begin dialysis, they should be revaccinated with a complete primary series.

Prevention and Management of HBV Infection

Preventing HBV transmission among chronic hemodialysis patients requires a) infection control precautions recommended for all hemodialysis patients; b) routine serologic testing for markers of HBV infection and prompt review of results; c) isolation of HBsAg-positive patients with dedicated room, machine, other equipment, supplies, and staff members; and d) vaccination. Additional infection control practices are needed because of the potential for environmentally mediated transmission of HBV, rather than internal contamination of dialysis machines. The need for routine follow-up testing, vaccination, or isolation is based on patients' serologic status (Table 1 and Recommended Practices at a Glance).

HBV-Susceptible Patients. Vaccinate all susceptible patients (see Hepatitis B Vaccination). Test susceptible patients monthly for HBsAg, including those who a) have not yet received hepatitis B vaccine, b) are in the process of being vaccinated, or c) have not adequately responded to vaccination. Although the incidence of HBV infection is low

among chronic hemodialysis patients, preventing transmission depends on timely detection of patients converting from HBsAg negative to HBsAg positive and rapid implementation of isolation procedures before cross-contamination can occur.

HBsAg Seroconversions. Report HBsAg-positive seroconversions to the local health department as required by law or regulation. When a seroconversion occurs, review all patients' routine laboratory test results to identify additional cases. Perform additional testing as indicated later in this section. Investigate potential sources for infection to determine if transmission might have occurred within the dialysis unit, including review of newly infected patients' recent medical history (e.g., blood transfusion, hospitalization), history of high-risk behavior (e.g., injecting-drug use, sexual activity), and unit practices and procedures.

In patients newly infected with HBV, HBsAg often is the only serologic marker initially detected; repeat HBsAg testing and test for anti-HBc (including IgM anti-HBc) 1–2 months later. Six months later, repeat HBsAg testing and test for anti-HBs to determine clinical outcome and need for counseling, medical evaluation, and vaccination of contacts. Patients who become HBsAg negative are no longer infectious and can be removed from isolation.

HBV-Infected Patients. To isolate HBsAg-positive patients, designate a separate room for their treatment and dedicate machines, equipment, instruments, supplies, and medications that will not be used by HBV-susceptible patients. Most importantly, staff members who are caring for HBsAg-positive patients should not care for susceptible patients at the same time, including during the period when dialysis is terminated on one patient and initiated on another.

Newly opened units should have isolation rooms for the dialysis of HBsAg-positive patients. For existing units in which a separate room is not possible, HBsAg-positive patients should be separated from HBV-susceptible patients in an area removed from the mainstream of activity and should undergo dialysis on dedicated machines. If a machine that has been used on an HBsAg-positive patient is needed for an HBV-susceptible patient, internal pathways of the machine can be disinfected using conventional protocols and external surfaces cleaned using soap and water or a detergent germicide.

Dialyzers should not be reused on HBsAg-positive patients. Because HBV is efficiently transmitted through occupational exposure to blood, reprocessing dialyzers from HBsAg-positive patients might place HBV-susceptible staff members at increased risk for infection.

Chronically infected patients (i.e., those who are HBsAg positive, total anti-HBc positive, and IgM anti-HBc negative) are infectious to others and are at risk for chronic liver disease. They should be counseled regarding preventing transmission to others, their household and sexual partners should receive hepatitis B vaccine, and they should be evaluated (by consultation or referral, if appropriate) for the presence or development of chronic liver disease according to current medical practice guidelines. Persons with chronic liver disease should be vaccinated against hepatitis A, if susceptible.

Chronically infected patients do not require any routine follow-up testing for purposes of infection control. However, annual testing for HBsAg is reasonable to detect the small percentage of HBV-infected patients who might lose their HBsAg.

HBV-Immune Patients. Annual anti-HBs testing of patients who are positive for anti-HBs (≥ 10 mIU/mL) and negative for anti-HBc determines the need for booster doses of

vaccine to ensure that protective levels of antibody are maintained. No routine follow-up testing is necessary for patients who are positive for both anti-HBs and anti-HBc.

HBV-immune patients can undergo dialysis in the same area as HBsAg-positive patients, or they can serve as a geographic buffer between HBsAg-positive and HBV-susceptible patients. Staff members can be assigned to care for both infected and immune patients on the same shift.

Isolated Anti-HBc-Positive Patients. Patients who test positive for isolated anti-HBc (i.e., those who are anti-HBc positive, HBsAg negative, and anti-HBs negative) should be retested on a separate serum sample for total anti-HBc, and if positive, for IgM anti-HBc. The following guidelines should be used for interpretation and follow-up:

- If total anti-HBc is negative, consider patient susceptible, and follow recommendations for vaccination.
- If total anti-HBc is positive and IgM anti-HBc is negative, follow recommendations for vaccination.
 - If anti-HBs is <10 mIU/mL even after revaccination, test for HBV DNA.
 - If HBV DNA is negative, consider patient susceptible (i.e., the anti-HBc result is a false positive), and test monthly for HBsAg.
 - If HBV DNA is positive, consider patient as having past infection or “low-level” chronic infection (i.e., the anti-HBc result is a true positive); no further testing is necessary.
 - Isolation is not necessary because HBsAg is not detectable.
- If both total and IgM anti-HBc are positive, consider patient recently infected and test for anti-HBs in 4–6 months; no further routine testing is necessary.
 - Isolation is not necessary because HBsAg is not detectable.

Prevention and Management of HCV Infection

HCV transmission within the dialysis environment can be prevented by strict adherence to infection control precautions recommended for all hemodialysis patients (see Recommended Practices at a Glance). Although isolation of HCV-infected patients is not recommended, routine testing for ALT and anti-HCV is important for monitoring transmission within centers and ensuring that appropriate precautions are being properly and consistently used.

HCV-Negative Patients. Monthly ALT testing will facilitate timely detection of new infections and provide a pattern from which to determine when exposure or infection might have occurred. In the absence of unexplained ALT elevations, testing for anti-HCV every 6 months should be sufficient to monitor the occurrence of new HCV infections. If unexplained ALT elevations are observed in patients who are anti-HCV negative, repeat anti-HCV testing is warranted. If unexplained ALT elevations persist in patients who repeatedly test anti-HCV negative, testing for HCV RNA should be considered.

Anti-HCV Seroconversions. Report anti-HCV–positive seroconversions to the local health department as required by law or regulation. When a seroconversion occurs, review all other patients’ routine laboratory test results to identify additional cases. Perform additional testing as indicated later in this section. Investigate potential sources

for infection to determine if transmission might have occurred within the dialysis unit, including review of newly infected patients' recent medical history (e.g., blood transfusion, hospitalization), history of high-risk behavior (e.g., injecting-drug use, sexual activity), and unit practices and procedures.

If ≥ 1 patient seroconverts from anti-HCV negative to positive during a 6-month period, more frequent (e.g., every 1–3 months) anti-HCV testing of HCV-negative patients could be warranted for a limited time (e.g., 3–6 months) to detect additional infections. If no additional newly infected patients are identified, resume semiannual testing. If ongoing HCV transmission among patients is identified, implement control measures based on results of investigation of potential sources for transmission and monitor their effectiveness (e.g., perform more frequent anti-HCV testing of HCV-negative patients for 6–12 months before resuming semiannual testing).

HCV-Positive Patients. Patients who are anti-HCV positive (or HCV RNA positive) do not have to be isolated from other patients or dialyzed separately on dedicated machines. Furthermore, they can participate in dialyzer reuse programs. Unlike HBV, HCV is not transmitted efficiently through occupational exposures. Thus, reprocessing dialyzers from HCV-positive patients should not place staff members at increased risk for infection.

HCV-positive persons should be evaluated (by consultation or referral, if appropriate) for the presence or development of chronic liver disease according to current medical practice guidelines. They also should receive information concerning how they can prevent further harm to their liver and prevent transmitting HCV to others (116,141). Persons with chronic liver disease should be vaccinated against hepatitis A, if susceptible.

Prevention and Management of HDV Infection

Because of the low prevalence of HDV infection in the United States, routine testing of hemodialysis patients is not necessary or recommended. However, if a patient is known to be infected with HDV, or if evidence exists of transmission of HDV in a dialysis center, screening for delta antibody is warranted. Because HDV depends on an HBV-infected host for replication, prevention of HBV infection will prevent HDV infection in a person susceptible to HBV. Patients who are known to be infected with HDV should be isolated from all other dialysis patients, especially those who are HBsAg-positive.

Prevention and Management of HIV Infection

Routine testing of hemodialysis patients for HIV infection for infection control purposes is not necessary or recommended. However, patients with risk factors for HIV infection should be tested so that, if infected, they can receive proper medical care and counseling regarding preventing transmission of the virus (201).

Infection control precautions recommended for all hemodialysis patients (see Recommended Practices at a Glance) are sufficient to prevent HIV transmission between patients. HIV-infected patients do not have to be isolated from other patients or dialyzed separately on dedicated machines. In addition, they can participate in dialyzer reuse programs. Because HIV is not transmitted efficiently through occupational exposures, reprocessing dialyzers from HIV-positive patients should not place staff members at increased risk for infection.

Prevention and Management of Bacterial Infections

Follow published guidelines for judicious use of antimicrobials, particularly vancomycin, to reduce selection for antimicrobial-resistant pathogens (202). Infection control precautions recommended for all hemodialysis patients (see Recommended Practices at a Glance) are adequate to prevent transmission for most patients infected or colonized with pathogenic bacteria, including antimicrobial-resistant strains. However, additional infection control precautions should be considered for treatment of patients who might be at increased risk for transmitting pathogenic bacteria. Such patients include those with either a) an infected skin wound with drainage that is not contained by dressings (the drainage does not have to be culture positive for VRE, MRSA, or any specific pathogen) or b) fecal incontinence or diarrhea uncontrolled with personal hygiene measures. For these patients, consider using the following additional precautions: a) staff members treating the patient should wear a separate gown over their usual clothing and remove the gown when finished caring for the patient and b) dialyze the patient at a station with as few adjacent stations as possible (e.g., at the end or corner of the unit).

SURVEILLANCE FOR INFECTIONS AND OTHER ADVERSE EVENTS

Develop and maintain a separate centralized record-keeping system (e.g., log book or electronic file) to record the results of patients' vaccination status, serologic testing results for viral hepatitis (including ALT), episodes of bacteremia or loss of the vascular access caused by infection (including date of onset, site of infection, genus and species of the infecting organism, and selected antimicrobial susceptibility results),* and adverse events (e.g., blood leaks and spills, dialysis machine malfunctions). Designate a staff person to promptly review the results of routine testing each time such testing is performed and periodically review recorded episodes of bacteremia or vascular access infections. Specify a procedure for actions required when changes occur in test results or in the frequency of episodes of bacteremias or vascular access loss because of infection. Maintain records for each patient that include the location of the dialysis station and machine number used for each dialysis session and the names of staff members who connect and disconnect the patient to and from a machine.

INFECTION CONTROL TRAINING AND EDUCATION

Training and education is recommended for both staff members and patients (or their family care givers). Training should be appropriate to the cognitive level of the staff member, patient, or family member, and rationales should be provided for appropriate infection control behaviors and techniques to increase compliance. Regulations and recommendations regarding infection control training for health-care workers in general, and dialysis personnel in particular, have been previously published

*Hemodialysis units interested in participating in a formal surveillance system for bacterial infections should consult CDC's Surveillance for Bloodstream and Vascular Access Infections in Outpatient Hemodialysis Centers. More information is available on the Internet at <http://www.cdc.gov/ncidod/hip/Dialysis/DSN_manual.PDF>.

(180,203–205). The following recommendations are intended to highlight and augment the earlier recommendations.

- Training and education for all employees at risk for occupational exposure to blood should be provided at least annually, given to new employees before they begin working in the unit, and documented. At a minimum, they should include information on the following topics:
 - proper hand hygiene technique;
 - proper use of protective equipment;
 - modes of transmission for bloodborne viruses, pathogenic bacteria, and other microorganisms as appropriate;
 - infection control practices recommended for hemodialysis units and how they differ from Standard Precautions recommended for other health-care settings;
 - proper handling and delivery of patient medications;
 - rationale for segregating HBsAg-positive patients with a separate room, machine, instruments, supplies, medications, and staff members;
 - proper infection control techniques for initiation, care, and maintenance of access sites;
 - housekeeping to minimize transmission of microorganisms, including proper methods to clean and disinfect equipment and environmental surfaces; and
 - centralized record keeping to monitor and prevent complications, including routine serologic testing results for HBV and HCV, hepatitis B vaccine status, episodes of bacteremia and loss of access caused by infection, and other adverse events. Records of surveillance for water and dialysate quality should also be maintained.
- Training and education of patients (or family members for patients unable to be responsible for their own care) regarding infection control practices should be given on admission to dialysis and at least annually thereafter and should address the following topics:
 - personal hygiene and hand washing technique;
 - patient responsibility for proper care of the access and recognition of signs of infection, which should be reviewed each time the patient has a change in access type; and
 - recommended vaccinations (206).

FUTURE DIRECTIONS

Infection control strategies that prevent and control HBV infection among hemodialysis patients are well-established. Areas that need additional research include determining the ideal hepatitis B vaccine dosage regimen for pre- and postdialysis pediatric patients and for predialysis adult patients, as well as the optimal timing for follow-up

testing and administration of booster doses among vaccine responders. In addition, further studies are needed to clarify the specific factors responsible for transmission of HCV among hemodialysis patients and to evaluate the effect of the current recommendations on prevention and control of HCV infection in this setting.

Many areas related to bacterial infections in chronic hemodialysis patients need additional information. Studies are needed on the prevalence and epidemiology of bacterial infections among chronic hemodialysis patients and the patient care practices (e.g., those related to vascular access care and puncture) that would be most useful in preventing bacterial infections. Because of the prominent role of dialysis patients in the epidemic of antimicrobial resistance, researchers need to learn more regarding optimal strategies to ensure judicious use of antimicrobials in these patients. Additional topics for future research include determining the frequency of transmission of pathogenic bacteria in the dialysis unit and whether additional precautions are necessary to prevent such transmission.

This document is available on the Internet at <<http://www.cdc.gov/hepatitis>>. Copies also can be obtained by using the order form at this Internet site or by writing the Hepatitis Branch, Mailstop G37, CDC, Atlanta, GA 30333.

References

1. National Institutes of Health. 1999 annual data report. US Renal Data System. Bethesda, MD: US Department of Health and Human Services, National Institute of Health, National Institute of Diabetes and Digestive and Kidney Diseases, April 1999.
2. Hörl WH. Neutrophil function and infections in uremia. *Am J Kidney Dis* 1999;33:xliv-ii.
3. Snyderman DR, Bryan JA, Hanson B. Hemodialysis-associated hepatitis in the United States—1972. *J Infect Dis* 1975;132:109–13.
4. Snyderman DR, Bregman D, Bryan J. Hemodialysis-associated hepatitis in the United States, 1974. *J Infect Dis* 1977;135:687–91.
5. Alter MJ, Favero MS, Petersen NJ, Doto IL, Leger RT, Maynard JE. National surveillance of dialysis-associated hepatitis and other diseases: 1976 and 1980. *Dialysis & Transplantation* 1983;12:860–5.
6. Alter MJ, Favero MS, Maynard JE. Hepatitis B vaccine use in chronic hemodialysis centers in the United States. *JAMA* 1985;254:3200–2.
7. Alter MJ, Favero MS, Maynard JE. Impact of infection control strategies on the incidence of dialysis-associated hepatitis in the United States. *J Infect Dis* 1986;153:1149–51.
8. Alter MJ, Favero MS, Miller JK, Moyer LA, Bland LA. National surveillance of dialysis-associated diseases in the United States, 1987. *ASAIO Transactions* 1989;35:820–31.
9. Alter MJ, Favero MS, Miller JK, Moyer LA, Bland LA. National surveillance of dialysis-associated diseases in the United States, 1988. *ASAIO Transactions* 1990;36:107–18.
10. Alter MJ, Favero MS, Miller JK, Moyer LA, Bland LA. National surveillance of dialysis-associated diseases in the United States, 1989. *ASAIO Transactions* 1991;37:97–109.
11. Tokars JI, Alter MJ, Favero MS, Moyer LA, Bland LA. National surveillance of hemodialysis associated diseases in the United States, 1990. *ASAIO J* 1993;39:71–80.
12. Tokars JI, Alter MJ, Favero MS, Moyer LA, Bland LA. National surveillance of dialysis associated diseases in the United States, 1991. *ASAIO J* 1993;39:966–75.
13. Tokars JI, Alter MJ, Favero MS, Moyer LA, Miller E, Bland LA. National surveillance of dialysis associated diseases in the United States, 1992. *ASAIO J* 1994;40:1020–31.
14. Tokars JI, Alter MJ, Favero MS, Moyer LA, Miller E, Bland LA. National surveillance of dialysis associated diseases in the United States, 1993. *ASAIO J* 1996;42:219–29.
15. Tokars JI, Alter MJ, Miller E, Moyer LA, Favero MS. National surveillance of dialysis associated diseases in the United States—1994. *ASAIO J* 1997;43:108–19.

16. Tokars JI, Miller ER, Alter MJ, Arduino MJ. National surveillance of dialysis associated diseases in the United States, 1995. *ASAIO J* 1998;44:98–107.
17. Tokars JI, Miller ER, Alter MJ, Arduino MJ. National surveillance of dialysis-associated diseases in the United States, 1996. Atlanta, GA: US Department of Health and Human Services, Public Health Service, CDC, 1998:1–59.
18. Tokars JI, Miller ER, Alter MJ, Arduino MJ. National surveillance of dialysis-associated diseases in the United States, 1997. *Semin Dial* 2000;13:75–85.
19. CDC. Hepatitis: control measures for hepatitis B in dialysis centers. Atlanta, GA: US Department of Health, Education, and Welfare, Public Health Services, CDC, 1977. HEW publication no. (CDC) 78-8358 (Viral Hepatitis Investigations and Control Series).
20. CDC. Recommendations of the Immunization Practices Advisory Committee (ACIP): inactivated hepatitis B virus vaccine. *MMWR* 1982;31:317–22, 327–8.
21. CDC. Outbreaks of hepatitis B virus infection among hemodialysis patients—California, Nebraska, and Texas, 1994. *MMWR* 1996;45:285–9.
22. Favero MS, Alter MJ. The reemergence of hepatitis B virus infection in hemodialysis centers. *Semin Dial* 1996;9:373–4.
23. Fridkin SK, Gaynes RP. Antimicrobial resistance in intensive care units. *Clin Chest Med* 1999;20:303–16.
24. Favero MS, Tokars JI, Arduino MJ, Alter MJ. Nosocomial infections associated with hemodialysis. In: Mayhall CG, ed. *Hospital epidemiology and infection control*, 2nd ed. Philadelphia, PA: Lippincott, Williams & Wilkins, 1999, 897–917.
25. Tokars JI. Description of a new surveillance system for bloodstream and vascular access infections in outpatient hemodialysis centers. *Semin Dial* 2000;13:97–100.
26. Alter HJ, Seeff LB, Kaplan PM, et al. Type B hepatitis: the infectivity of blood positive for e antigen and DNA polymerase after accidental needlestick exposure. *N Engl J Med* 1976;295:909–13.
27. Shikata T, Karasawa T, Abe K, et al. Hepatitis B e antigen and infectivity of hepatitis B virus. *J Infect Dis* 1977;136:571–6.
28. Favero MS, Bond WW, Petersen NJ, Berquist KR, Maynard JE. Detection methods for study of the stability of hepatitis B antigen on surfaces. *J Infect Dis* 1974;129:210–2.
29. Bond WW, Favero MS, Petersen NJ, Gravelle CR, Ebert JW, Maynard JE. Survival of hepatitis B virus after drying and storage for one week. *Lancet* 1981;1:550–1.
30. Favero MS, Maynard JE, Petersen NJ, et al. Hepatitis-B antigen on environmental surfaces [Letter]. *Lancet* 1973;2:1455.
31. Snyderman DR, Bryan JA, Macon EJ, Gregg MB. Hemodialysis-associated hepatitis: report of an epidemic with further evidence on mechanisms of transmission. *Am J Epidemiol* 1976;104:563–70.
32. Kantor RJ, Hadler SC, Schreeder MT, et al. Outbreak of hepatitis B in a dialysis unit, complicated by false positive HBsAg test results. *Dialysis & Transplantation* 1979;8:232–5.
33. Carl M, Francis DP, Maynard JE. A common-source outbreak of hepatitis B in a hemodialysis unit. *Dialysis & Transplantation* 1983;12:222–9.
34. Alter MJ, Ahtone J, Maynard JE. Hepatitis B virus transmission associated with a multiple-dose vial in a hemodialysis unit. *Ann Intern Med* 1983;99:330–3.
35. Niu MT, Penberthy LT, Alter MJ, Armstrong CW, Miller GB, Hadler SC. Hemodialysis-associated hepatitis B: report of an outbreak. *Dialysis & Transplantation* 1989;18:542–6, 555.
36. Anonymous. Decrease in the incidence of hepatitis in dialysis units associated with prevention programme: Public Health Laboratory Service Survey. *BMJ* 1974;4:751–4.
37. Anonymous. Hepatitis B in retreat from dialysis units in United Kingdom in 1973: Public Health Laboratory Service Survey. *Br Med J* 1976;1:1579–81.
38. Najem GR, Louria DB, Thind IS, et al. Control of hepatitis B infection: the role of surveillance and an isolation hemodialysis center. *JAMA* 1981;245:153–7.

39. Hutin YJF, Goldstein ST, Varma JK, et al. An outbreak of hospital-acquired hepatitis B virus infection among patients receiving hemodialysis. *Infect Control Hosp Epidemiol* 1999;20:731–5.
40. McMahon BJ, Alward WLM, Hall DB, et al. Acute hepatitis B virus infection: relation of age to the clinical expression of disease and subsequent development of the carrier state. *J Infect Dis* 1985;151:599–603.
41. Dienstag JL. Immunopathogenesis of the extrahepatic manifestations of hepatitis B virus infections. *Springer Semin Immunopathol* 1981;3:461–72.
42. Hoofnagle JH, Di Bisceglie AM. Serologic diagnosis of acute and chronic viral hepatitis. *Semin Liver Dis* 1991;11:73–83.
43. Beasley RP, Hwang L-Y, Lin C-C, Chin C-S. Hepatocellular carcinoma and hepatitis B virus: a prospective study of 22,707 men in Taiwan. *Lancet* 1981;2:1129–33.
44. Hoofnagle JH, Shafritz DA, Popper H. Chronic type B hepatitis and the “healthy” HBsAg carrier state. *Hepatology* 1987;7:758–63.
45. McMahon BJ, Alberts SR, Wainwright RB, Bulkow L, Lanier AP. Hepatitis B-related sequelae: prospective study in 1400 hepatitis B surface antigen—positive Alaska Native carriers. *Arch Intern Med* 1990;150:1051–4.
46. Ortiz-Interian CJ, de Medina MD, Perez GO, et al. Recurrence and clearance of hepatitis B surface antigenemia in a dialysis patient infected with the human immunodeficiency virus. *Am J Kidney Dis* 1990;xvi:154–6.
47. Davis CL, Gretch DR, Carithers RL. Hepatitis B and transplantation. *Infect Dis Clin North Am* 1995;9:925–41.
48. Hoofnagle JH, Di Bisceglie AM. The treatment of chronic viral hepatitis. *N Engl J Med* 1997;336:347–56.
49. Dienstag JL, Schiff ER, Wright TL, et al. Lamivudine as initial treatment for chronic hepatitis B in the United States. *N Engl J Med* 1999;341:1256–63.
50. Kloster B, Kramer R, Eastlund T, Grossman B, Zarva B. Hepatitis B surface antigenemia in blood donors following vaccination. *Transfusion* 1995;35:475–7.
51. Lunn ER, Hoggarth BJ, Cook WJ. Prolonged hepatitis B surface antigenemia after vaccination. *Pediatrics* 2000;105:E81.
52. Hadler SC, Murphy B, Schable CA, Heyward WL, Francis DP, Kane MA. Epidemiological analysis of the significance of low-positive test results for antibody to hepatitis B surface and core antigens. *J Clin Microbiol* 1984;19:521–5.
53. Levine OS, Vlahov D, Koehler J, Cohn W, Spronk AM, Nelson KE. Seroepidemiology of hepatitis B virus in a population of injecting drug users: association with drug injection patterns. *Am J Epidemiol* 1995;142:331–41.
54. Silva AE, McMahon BJ, Parkinson AJ, Sjogren MH, Hoofnagle JH, Di Bisceglie AM. Hepatitis B virus DNA in persons with isolated antibody to hepatitis B core antigen who subsequently received hepatitis B vaccine. *Clin Infect Dis* 1998;26:895–7.
55. McMahon BJ, Parkinson AJ, Helminiak C, et al. Response to hepatitis B vaccine of persons positive for antibody to hepatitis B core antigen. *Gastroenterology* 1992;103:590–4.
56. Lai C-L, Lau JYN, Yeoh E-K, Chang W-K, Lin H-S. Significance of isolated anti-HBc seropositivity by ELISA: implications and the role of radioimmunoassay. *J Med Virol* 1992;36:180–3.
57. Lai C-L, Chien R-N, Leung NWY, et al, and the Asia Hepatitis Lamivudine Study Group. A one-year trial of lamivudine for chronic hepatitis B. *N Engl J Med* 1998;339:61–8.
58. Hadler SC, Margolis HS. Hepatitis B immunization: vaccine types, efficacy, and indications for immunization. In: Remington JS, Swartz MN, eds. *Current clinical topics in infectious diseases*. Boston, MA: Blackwell Scientific Publications, 1992:282–308.
59. Averbhoff F, Mahoney F, Coleman P, Schatz G, Hurwitz E, Margolis H. Immunogenicity of hepatitis B vaccines: implications for persons at occupational risk of hepatitis B virus infection. *Am J Prev Med* 1998;15:1–8.

60. Maupas P, Goudeau A, Coursaget P, et al. Vaccine against hepatitis B—18 months prevention in a high risk setting. *Med Microbiol Immunol (Berl)* 1978;166:109–18.
61. Grob P. Hepatitis B vaccination of renal transplant and hemodialysis patients. *Scand J Infect Dis* 1983;38:28–32.
62. Stevens CE, Alter HJ, Taylor PE, Zang EA, Harley EJ, Szmunes W, and the Dialysis Vaccine Trial Study Group. Hepatitis B vaccine in patients receiving hemodialysis: immunogenicity and efficacy. *N Engl J Med* 1984;311:496–501.
63. de Graeff PA, Dankert J, de Zeeuw D, Gips CH, van der Hem GK. Immune response to two different hepatitis B vaccines in haemodialysis patients: a 2-year follow-up. *Nephron* 1985;40:155–60.
64. Carletti P, Bibiano L, Boggi R, et al. HBV infection in hemodialysis patients: monitoring and prevention. *Nephron* 1992;61:269–70.
65. Navarro JF, Teruel JL, Mateos ML, Marcen R, Ortuño J. Antibody level after hepatitis B vaccination in hemodialysis patients: influence of hepatitis C virus infection. *Am J Nephrol* 1996;16:95–7.
66. van Geelen JA, Schalm SW, de Visser EM, Heijtkink RA. Immune response to hepatitis B vaccine in hemodialysis patients. *Nephron* 1987;45:216–8.
67. Bruguera M, Cremades M, Mayor A, Sánchez Tapias JM, Rodés J. Immunogenicity of a recombinant hepatitis B vaccine in haemodialysis patients. *Postgrad Med J* 1987;63(Supp 2):155–8.
68. Bruguera M, Rodicio JL, Alcazar JM, Oliver A, Del Rio G, Esteban-Mur R. Effects of different dose levels and vaccination schedules on immune response to a recombinant DNA hepatitis B vaccine in haemodialysis patients. *Vaccine* 1990;8(Suppl):S47–S49.
69. Waite NM, Thomson LG, Goldstein MB. Successful vaccination with intradermal hepatitis B vaccine in hemodialysis patients previously nonresponsive to intramuscular hepatitis B vaccine. *J Am Soc Nephrol* 1995;5:1930–4.
70. Chang PC, Schrandt-van der Meer AM, van Dorp WT, van Leer E. Intracutaneous versus intramuscular hepatitis B vaccination in primary non-responding haemodialysis patients. *Nephrol Dial Transplant* 1996;11:191–3.
71. Swan AM, DeVita MV. Higher response rate to hepatitis B vaccination observed in chronic hemodialysis patients [Letter]. *Clin Nephrol* 1997;47:207–8.
72. Radovic MM, Ostric V, Djukanovic LJ. Complete seroconversion after vaccination against hepatitis B virus in hemodialysis patients [Letter]. *Clin Nephrol* 1997;47:206.
73. Navarro JF, Teruel JL, Mateos M, Ortuño J. Hepatitis C virus infection decreases the effective antibody response to hepatitis B vaccine in hemodialysis patients. *Clin Nephrol* 1994;41:113–6.
74. Kamel M, El Manialawi M, Miller DF. Recombinant hepatitis B vaccine immunogenicity in presence of hepatitis C virus seropositivity [Letter]. *Lancet* 1994;343:552.
75. Cheng C-H, Huang C-C, Leu M-L, Chiang C-YF, Wu M-S, Lai P-C. Hepatitis B vaccine in hemodialysis patients with hepatitis C viral infection. *Vaccine* 1997;15:1353–7.
76. Fraser GM, Ochana N, Fenyves D, et al. Increasing serum creatinine and age reduce the response to hepatitis B vaccine in renal failure patients. *J Hepatol* 1994;21:450–4.
77. Seaworth B, Drucker J, Starling J, Drucker R, Stevens C, Hamilton J. Hepatitis B vaccine in patients with chronic renal failure before dialysis. *J Infect Dis* 1988;157:332–7.
78. Dukes CS, Street AC, Starling JF, Hamilton JD. Hepatitis B vaccination and booster in predialysis patients: a 4-year analysis. *Vaccine* 1993;11:1229–32.
79. Callis LM, Clanxet J, Fortuny G, Caballeria J, Carrasco JL, Lardinois R. Hepatitis B virus infection and vaccination in children undergoing hemodialysis. *Acta Paediatr* 1985;74:213–8.
80. Drachman R, Isacson M, Rudensky B, Drukker A. Vaccination against hepatitis B in children and adolescent patients on dialysis. *Nephrol Dial Transplant* 1989;4:372–4.
81. Watkins SL, Hogg RJ, Alexander SR, Brewer ED, Bailey SM, Burns JL. Response to recombinant hepatitis B vaccine (Recombivax HB®) in children with chronic renal failure. [Abstract 14P]. *J Am Soc Nephrol* 1994;5:344.

82. Vazquez G, Mendoza-Guevara L, Alvarez T, et al. Comparison of the response to the recombinant vaccine against hepatitis B virus in dialyzed and nondialyzed children with CRF using different doses and routes of administration. *Adv Perit Dial* 1997;13:291–6.
83. Szmunness W, Stevens CE, Harley EJ, et al. Hepatitis B vaccine: demonstration of efficacy in a controlled clinical trial in a high-risk population in the United States. *N Engl J Med* 1980;303:833–41.
84. Hadler SC, Francis DP, Maynard JE, et al. Long-term immunogenicity and efficacy of hepatitis B vaccine in homosexual men. *N Engl J Med* 1986;315:209–14.
85. Crosnier J, Jungers P, Couroucé A-M, et al. Randomised placebo-controlled trial of hepatitis B surface antigen vaccine in French haemodialysis units: II, haemodialysis patients. *Lancet* 1981;1:797–800.
86. Desmyter J, Colaert J, De Groote G, et al. Efficacy of heat-inactivated hepatitis B vaccine in haemodialysis patients and staff: double-blind placebo-controlled trial. *Lancet* 1983;2:1323–8.
87. Miller ER, Alter MJ, Tokars JI. Protective effect of hepatitis B vaccine in chronic hemodialysis patients. *Am J Kidney Dis* 1999;33:356–60.
88. Alter MJ, Favero MS, Francis DP. Cost benefit of vaccination for hepatitis B in hemodialysis centers. *J Infect Dis* 1983;148:770–1.
89. CDC. Hepatitis B virus: a comprehensive strategy for eliminating transmission in the United States through universal childhood vaccination—recommendations of the Immunization Practices Advisory Committee (ACIP). *MMWR* 1991;40(No. RR-13):1–25.
90. Rawer P, Willems WR, Breidenbach T, Guttman W, Pabst W, Schütterle G. Seroconversion rate, hepatitis B vaccination, hemodialysis, and zinc supplementation. *Kidney Int* 1987;32(Suppl 22):S149–S152.
91. Mettang T, Weber J, Schenk U, Machleidt C, Kuhlmann U. Intradermal hepatitis B vaccination in nonresponsive hemodialysis patients [Letter]. *Ren Fail* 1993;15:655–6.
92. Rault R, Freed B, Nespors S, Bender F. Efficacy of different hepatitis B vaccination strategies in patients receiving hemodialysis. *ASAIO J* 1995;41:M717–M719.
93. Haubitz M, Ehlerding G, Beigel A, Heuer U, Hemmerling AE, Thoma HA. Clinical experience with a new recombinant hepatitis-B vaccine in previous non-responders with chronic renal insufficiency. *Clin Nephrol* 1996;45:180–2.
94. Fabrizi F, Andrulli S, Bacchini G, Corti M, Locatelli F. Intradermal versus intramuscular hepatitis B re-vaccination in non-responsive chronic dialysis patients: a prospective randomized study with cost-effectiveness evaluation. *Nephrol Dial Transplant* 1997;12:1204–11.
95. Wainwright RB, McMahon BJ, Bulkow LR, et al. Duration of immunogenicity and efficacy of hepatitis B vaccine in a Yupik Eskimo population. *JAMA* 1989;261:2362–6.
96. West DJ, Calandra GB. Vaccine induced immunologic memory for hepatitis B surface antigen: implications for policy on booster vaccination [Review]. *Vaccine* 1996;14:1019–27.
97. Mahoney FJ, Stewart K, Hu H, Coleman P, Alter MJ. Progress toward the elimination of hepatitis B virus transmission among health care workers in the United States. *Arch Intern Med* 1997;157:2601–5.
98. Yuen M-F, Lim W-L, Cheng C-C, Lam S-K, Lai C-L. Twelve-year follow-up of a prospective randomized trial of hepatitis B recombinant DNA yeast vaccine versus plasma-derived vaccine without booster doses in children. *Hepatology* 1999;29:924–7.
99. Grob PJ, Binswanger U, Zaruba K, et al. Immunogenicity of a hepatitis B subunit vaccine in hemodialysis and in renal transplant recipients. *Antiviral Res* 1983;3:43–52.
100. Jilg W, Schmidt M, Weinel B, et al. Immunogenicity of recombinant hepatitis B vaccine in dialysis patients. *J Hepatol* 1986;3:190–5.
101. Pasko MT, Bartholomew WR, Beam TR Jr, Amsterdam D, Cunningham EE. Long-term evaluation of the hepatitis B vaccine (Heptavax-B) in hemodialysis patients. *Am J Kidney Dis* 1988;xi:326–31.

102. Fabrizi F, Di Filippo S, Marcelli D, et al. Recombinant hepatitis B vaccine use in chronic hemodialysis patients: long-term evaluation and cost-effectiveness analysis. *Nephron* 1996;72:536–43.
103. Peces R, de la Torre M, Alcazar R, Urrea JM. Prospective analysis of the factors influencing the antibody response to hepatitis B vaccine in hemodialysis patients. *Am J Kidney Dis* 1997;29:239–45.
104. Oliveira PMC, Silva AE, Kemp VL, Juliano Y, Ferraz ML. Comparison of three different schedules of vaccination against hepatitis B in health care workers. *Vaccine* 1995;13:791–4.
105. Yamashiki M, Kosaka Y, Nishimura A. An effective intradermal hepatitis B vaccination. *Vaccine* 1997;15:1618–23.
106. Cardell K, Frydén A, Normann B. Intradermal hepatitis B vaccination in health care workers. Response rate and experiences from vaccination in clinical practice. *Scand J Infect Dis* 1999;31:197–200.
107. Alter MJ, Hadler SC, Judson FN, et al. Risk factors for acute non-A, non-B hepatitis in the United States and association with hepatitis C virus infection. *JAMA* 1990;264:2231–5.
108. Donahue JG, Muñoz A, Ness PM, et al. The declining risk of post-transfusion hepatitis C virus infection. *N Engl J Med* 1992;327:369–73.
109. Niu MT, Coleman PJ, Alter MJ. Multicenter study of hepatitis C virus infection in chronic hemodialysis patients and hemodialysis center staff members. *Am J Kidney Dis* 1993;22:568–73.
110. Fabrizi F, Martin P, Dixit V, et al. Acquisition of hepatitis C virus in hemodialysis patients: a prospective study by branched DNA signal amplification assay. *Am J Kidney Dis* 1998;31:647–54.
111. Zeldis JB, Depner TA, Kuramoto IK, Gish RG, Holland PV. The prevalence of hepatitis C virus antibodies among hemodialysis patients. *Ann Intern Med* 1990;112:958–60.
112. Hardy NM, Sandroni S, Danielson S, Wilson WJ. Antibody to hepatitis C virus increases with time on hemodialysis. *Clin Nephrol* 1992;38:44–8.
113. Jonas MM, Zilleruelo GE, LaRue SI, Abitbol C, Strauss J, Lu Y. Hepatitis C infection in a pediatric dialysis population. *Pediatrics* 1992;89:707–9.
114. Moyer LA, Alter MJ. Hepatitis C virus in the hemodialysis setting: a review with recommendations for control. *Semin Dial* 1994;7:124–7.
115. Selgas R, Martinez-Zapico R, Bajo MA, et al. Prevalence of hepatitis C antibodies (HCV) in a dialysis population at one center. *Perit Dial Int* 1992;12:28–30.
116. CDC. Recommendations for prevention and control of hepatitis C virus (HCV) infection and HCV-related chronic disease. *MMWR* 1998;47(No. RR-19):1–39.
117. Chan TM, Lok ASF, Cheng IKP, Chan RT. Prevalence of hepatitis C virus infection in hemodialysis patients: a longitudinal study comparing the results of RNA and antibody assays. *Hepatology* 1993;17:5–8.
118. Sampietro M, Salvadori S, Corbetta N, Badalamenti S, Graziani G, Fiorelli G. Single-tube reverse transcription and heminested polymerase chain reaction of hepatitis C virus RNA to detect viremia in serologically negative hemodialysis patients. *Int J Clin Lab Res* 1995;25:52–4.
119. Stuyver L, Claeys H, Wyseur A, et al. Hepatitis C virus in a hemodialysis unit: molecular evidence for nosocomial transmission. *Kidney Int* 1996;49:889–95.
120. Schröter M, Feucht H-H, Schäfer P, Zöllner B, Laufs R. High percentage of seronegative HCV infections in hemodialysis patients: the need for PCR. *Intervirology* 1997;40:277–8.
121. Le Pogam S, Le Chapois D, Christen R, Dubois F, Barin F, Gaudeau A. Hepatitis C in a hemodialysis unit: molecular evidence for nosocomial transmission. *J Clin Micro* 1998;36:3040–3.
122. Alter HJ, Jett BW, Polito AJ, et al. Analysis of the role of hepatitis C virus in transfusion-associated hepatitis. In: Hollinger FB, Lemon SM, Margolis H, eds. *Viral hepatitis and liver disease*. Baltimore, MD: Williams & Williams, 1991:396–402.

123. Alter HJ, Seeff LB. Recovery, persistence, and sequelae in hepatitis C virus infection: a perspective on long-term outcome. *Semin Liver Dis* 2000;20:17–35.
124. Pol S, Romeo R, Zins B, et al. Hepatitis C virus RNA in anti-HCV positive hemodialyzed patients: significance and therapeutic implications. *Kidney Int* 1993;44:1097–100.
125. Gubertini G, Scorza D, Beccari M, et al. Prevalence of hepatitis C virus antibodies in hemodialysis patients in the area of Milan. *Nephron* 1992;61:271–2.
126. Bukh J, Wantzin P, Krogsgaard K, Knudsen F, Purcell RH, Miller RH, and the Copenhagen Dialysis HCV Study Group. High prevalence of hepatitis C virus (HCV) RNA in dialysis patients: failure of commercially available antibody tests to identify a significant number of patients with HCV infection. *J Infect Dis* 1993;168:1343–8.
127. Sakamoto N, Enomoto N, Marumo F, Sato C. Prevalence of hepatitis C virus infection among long-term hemodialysis patients: detection of hepatitis C virus RNA in plasma. *J Med Virol* 1993;39:11–5.
128. Picciotto A, Varagona G, Gurreri G, et al. Anti-hepatitis C virus antibodies and hepatitis C virus viraemia in haemodialysis patients. *Nephrol Dial Transplant* 1993;8:1115–7.
129. Silini E, Bono F, Cerino A, Piazza V, Solcia E, Mondelli MU. Virological features of hepatitis C virus infection in hemodialysis patients. *J Clin Microbiol* 1993;31:2913–7.
130. Kuhns M, de Medina M, McNamara A, et al. Detection of hepatitis C virus RNA in hemodialysis patients. *J Am Soc Nephrol* 1994;4:1491–7.
131. Oliva JA, Ercilla G, Mallafre JM, Bruguera M, Carrió J, Pereira BJ. Markers of hepatitis C infection among hemodialysis patients with acute and chronic infection: implications for infection control strategies in hemodialysis units. *Int J Artif Organs* 1995;18:73–7.
132. Dussol B, de Lamballerie X, Brunet P, et al. Is hepatitis C virus-RNA detection by nested polymerase chain reaction clinically relevant in hemodialysis patients? *Clin Nephrol* 1996;45:257–60.
133. Pujol FH, Ponce JG, Lema MG, et al. High incidence of hepatitis C virus infection in hemodialysis patients in units with high prevalence. *J Clin Microbiol* 1996;34:1633–6.
134. Caramelo C, Bartolomé J, Albalade M, et al. Undiagnosed hepatitis C virus infection in hemodialysis patients: value of HCV RNA and liver enzyme levels. *Kidney Int* 1996;50:2027–31.
135. Fabrizi F, Lunghi G, Andrulli S, et al. Influence of hepatitis C virus (HCV) viraemia upon serum aminotransferase activity in chronic dialysis patients. *Nephrol Dial Transplant* 1997;12:1394–8.
136. Cristina G, Piazza V, Efficace E, et al. A survey of hepatitis C virus infection in haemodialysis patients over a 7-year follow-up. *Nephrol Dial Transplant* 1997;12:2208–10.
137. Koff RS, Dienstag JL. Extrahepatic manifestations of hepatitis C and the association with alcoholic liver disease. *Semin Liver Dis* 1995;15:101–9.
138. Alter MJ, Kruszon-Moran D, Nainan OV, et al. The prevalence of hepatitis C virus infection in the United States, 1988 through 1994. *N Engl J Med* 1999;341:556–62.
139. Bukh J, Miller RH, Purcell RH. Genetic heterogeneity of hepatitis C virus: quasispecies and genotypes. *Semin Liver Dis* 1995;15:41–63.
140. McHutchinson JG, Gordon SC, Schiff ER, et al. Interferon alfa-2b alone or in combination with ribavirin as initial treatment for chronic hepatitis C. *N Engl J Med* 1998;339:1485–92.
141. National Institutes of Health. Chronic hepatitis C: current disease management. Available on the Internet at <<http://www.niddk.nih.gov/health/digest/pubs/chrnhepc/chrnchepc.htm>>. Accessed January 11, 2001.
142. Zacks S, Fried MW. Hepatitis C and renal disease. In: Liang TJ, Hoofnagle JH, eds. *Hepatitis C: biomedical research reports*. San Diego, CA: Academic Press, 2000:329–49.
143. Alter MJ, Margolis HS, Krawczynski K, et al, and the Sentinel Counties Chronic Non-A, Non-B Hepatitis Study Team. The natural history of community-acquired hepatitis C in the United States. *N Engl J Med* 1992;327:1899–1905.

144. Ridzon R, Gallagher K, Ciesielski C, et al. Simultaneous transmission of human immunodeficiency virus and hepatitis C virus from a needle-stick injury. *N Engl J Med* 1997;336:919–22.
145. CDC. Public Health Service inter-agency guidelines for screening donors of blood, plasma, organs, tissue, and semen for evidence of hepatitis B and hepatitis C. *MMWR* 1991;40(No. RR-4):1–17.
146. Kleinman S, Alter HJ, Busch M, et al. Increased detection of hepatitis C virus (HCV)-infected blood donors by a multiple-antigen HCV enzyme immunoassay. *Transfusion* 1992;32:805–13.
147. Bouchardeau F, Chauveau P, Le Marrec N, Girault A, Zins B, Couroucé AM. Detection of hepatitis C virus by polymerase chain reaction in haemodialysed patients in relationship to anti-HCV status. *Res Virol* 1993;144:233–42.
148. Seelig R, Renz M, Bottner C, Seelig HP. Hepatitis C virus infections in dialysis units: prevalence of HCV-RNA and antibodies to HCV. *Ann Med* 1994;26:45–52.
149. Al Meshari K, Al Ahdal M, Alfurayh O, Ali A, Devol E, Kessie G. New insights into hepatitis C virus infection of hemodialysis patients: the implications. *Am J Kidney Dis* 1995;25:572–8.
150. Fabrizi F, Lunghi G, Pagliari B, et al. Molecular epidemiology of hepatitis C virus infection in dialysis patients. *Nephron* 1997;77:190–6.
151. Umlauf F, Gruenewald K, Weiss G, et al. Patterns of hepatitis C viremia in patients receiving hemodialysis. *Am J Gastroenterol* 1997;92:73–8.
152. Schneeberger PM, Keur I, van der Vliet W, et al. Hepatitis C virus infections in dialysis centers in the Netherlands: a national survey of serological and molecular methods. *J Clin Microbiol* 1998;36:1711–5.
153. Casanovas Taltavull T, Baliellas C, Sesé E, et al. Interferon may be useful in hemodialysis patients with hepatitis C virus chronic infection who are candidates for kidney transplant. *Transplant Proc* 1995;27:2229–30.
154. Dalekos GN, Boumba DS, Katopodis K, et al. Absence of HCV viraemia in anti-HCV-negative haemodialysis patients. *Nephrol Dial Transplant* 1998;13:1804–6.
155. Davis GL, Lau JY-N, Urdea MS, et al. Quantitative detection of hepatitis C virus RNA with a solid-phase signal amplification method: definition of optimal conditions for specimen collection and clinical application in interferon-treated patients. *Hepatology* 1994;19:1337–41.
156. Roth WK, Lee J-H, Rüster B, Zeuzem S. Comparison of two quantitative hepatitis C virus reverse transcriptase PCR assays. *J Clin Micro* 1996;34:261–4.
157. Pawlotsky J-M. Measuring hepatitis C viremia in clinical samples: can we trust the assays? [Review] *Hepatology* 1997;26:1–4.
158. Hadler SC, Fields HA. Hepatitis delta virus. In: Belshe RB, ed. *Textbook of Human virology*, 2nd ed. St Louis, MO: Mosby Year Book, 1991:749–65.
159. Lettau LA, Alfred HJ, Glew RH, et al. Nosocomial transmission of delta hepatitis. *Ann Intern Med* 1986;104:631–5.
160. Velandia M, Fridkin SK, Cárdenas V, et al. Transmission of HIV in dialysis centre. *Lancet* 1995;345:1417–22.
161. Sulkowski MS, Thomas DL, Chaisson RC, Moore RD. Hepatotoxicity associated with antiretroviral therapy in adults infected with human immunodeficiency virus and the role of hepatitis C or B virus infection. *JAMA* 2000;283:74–80.
162. Keane WF, Shapiro FL, Raji L. Incidence and type of infections occurring in 445 chronic hemodialysis patients. *Trans Am Soc Artif Intern Organs* 1977;xxiii:41–7.
163. Dobkin JF, Miller MH, Steigbigel NH. Septicemia in patients on chronic hemodialysis. *Ann Intern Med* 1978;88:28–33.
164. Kaplowitz LG, Comstock JA, Landwehr DM, Dalton HP, Mayhall CG. A prospective study of infections in hemodialysis patients: patient hygiene and other risk factors for infection. *Infect Control Hosp Epidemiol* 1988;9:534–41.

165. Kessler M, Hoen B, Mayeux D, Hestin D, Fontenaille C. Bacteremia in patients on chronic hemodialysis: a multicenter prospective survey. *Nephron* 1993;64:95–100.
166. Bloembergen WE, Port FK. Epidemiological perspective on infections in chronic dialysis patients. *Adv Ren Replace Ther* 1995;3:201–7.
167. Bonomo RA, Rice D, Whalen C, Linn D, Eckstein E, Shlaes DM. Risk factors associated with permanent access-site infections in chronic hemodialysis patients. *Infect Control Hosp Epidemiol* 1997;18:757–61.
168. Hoen B, Paul-Dauphin A, Hestin D, Kessler M. EPIBACDIAL: a multicenter prospective study of risk factors for bacteremia in chronic hemodialysis patients. *J Am Soc Nephrol* 1998;9:869–76.
169. Tokars JI, Light P, Armistead N, et al. Surveillance for infections in hemodialysis patients: a pilot study [Abstract]. *Infect Control Hosp Epidemiol* 2000;21:101.
170. Stevenson KB, Adcox MJ, Mallea MC, Narasimhan N, Wagnild JP. Standardized surveillance of hemodialysis vascular access infections: 18-month experience at an outpatient, multifacility hemodialysis center. *Infect Control Hosp Epidemiol* 2000;21:200–3.
171. Tokars JI, Alter MJ, Arduino MJ. Nosocomial infections in hemodialysis units: strategies for control. In: Owen WF, Pereira BJG, Sayegh MH, eds. *Dialysis and transplantation: a companion to Brenner and Rector's THE KIDNEY*. Philadelphia, PA: W.B. Saunders Company, 2000, 337–57.
172. Churchill DN, Taylor DW, Cook RJ, et al. Canadian hemodialysis morbidity study. *Am J Kidney Dis* 1992;xix:214–34.
173. Fan P-Y, Schwab SJ. Vascular access: concepts for the 1990s [Review]. *J Am Soc Nephrol* 1992;3:1–11.
174. Besarab A, Bolton WK, Browne JK, et al. The effects of normal as compared with low hematocrit values in patients with cardiac disease who are receiving hemodialysis and epoetin. *N Engl J Med* 1998;339:584–90.
175. Powe NR, Jaar B, Furth SL, Hermann J, Briggs W. Septicemia in dialysis patients: incidence, risk factors, and prognosis. *Kidney Int* 1999;55:1081–90.
176. CDC. Outbreaks of gram-negative bacterial bloodstream infections traced to probable contamination of hemodialysis machines—Canada, 1995; United States, 1997; and Israel, 1997. *MMWR* 1998;47:55–9.
177. Grohskopf LA, Roth VR, Feiken D, et al. *Serratia liquifaciens* bloodstream infections and pyrogenic reactions associated with extrinsically contaminated erythropoietin [Abstract]. *Infect Control Hosp Epidemiol* 2000;21:136.
178. Shay DK, Maloney SA, Montecalvo M, et al. Epidemiology and mortality risk of vancomycin-resistant enterococcal bloodstream infections. *J Infect Dis* 1995;172:993–1000.
179. Jarvis WR. The epidemiology of colonization. *Infect Control Hosp Epidemiol* 1996;17:47–52.
180. National Kidney Foundation. Dialysis outcomes quality initiative. Clinical practice guidelines. *Am J Kidney Dis* 1997;30(Suppl 3):S137–S240. Available on the Internet at <<http://www.kidney.org>>.
181. Smith TL, Pearson ML, Wilcox KR, et al. Emergence of vancomycin resistance in *Staphylococcus aureus*. Glycopeptide-Intermediate *Staphylococcus aureus* Working Group. *N Engl J Med* 1999;340:493–501.
182. CDC. *Staphylococcus aureus* with reduced susceptibility to vancomycin—Illinois, 1999. *MMWR* 1999;48:1165–7.
183. Raad I, Alrahwani A, Rolston K. *Staphylococcus epidermidis*: emerging resistance and need for alternative agents. *Clin Infect Dis* 1998;26:1182–7.
184. Garrett DO, Jochimsen E, Murfitt K, et al. The emergence of decreased susceptibility to vancomycin in *Staphylococcus epidermidis*. *Infect Control Hosp Epidemiol* 1999;20:167–70.
185. Uttley AHC, George RC, Naidoo J, et al. High-level vancomycin-resistant enterococci causing hospital infections. *Epidemiol Infect* 1989;103:173–81.
186. Stroud L, Edwards J, Danzig L, Culver D, Gaynes R. Risk factors for mortality associated with enterococcal blood stream infections. *Infect Control Hosp Epidemiol* 1996;17:576–80.

187. Singer DA, Jochimsen EM, Gielerak P, Jarvis WR. Pseudo-outbreak of *Enterococcus durans* infections and colonization associated with introduction of an automated identification system software update. *J Clin Microbiol* 1996;34:2685–7.
188. Fishbane S, Cunha BA, Mittal SK, Ruggian J, Shea K, Schoch PE. Vancomycin-resistant enterococci in hemodialysis patients is related to intravenous vancomycin use [Letter]. *Infect Control Hosp Epidemiol* 1999;20:461–2.
189. Tokars JI, Gehr T, Parrish J, Qaiyumi S, Light P. Vancomycin-resistant enterococci colonization at selected outpatient hemodialysis centers [Abstract]. *Infect Control Hosp Epidemiol* 2000;21:101.
190. Fogel MA, Nussbaum PB, Feintzeig ID, Hunt WA, Gavin JR, Kim RC. Cefazolin in chronic hemodialysis patients: a safe, effective alternative to vancomycin. *Am J Kidney Dis* 1998;32:401–9.
191. Brady JP, Snyder JW, Hasbargen JA. Vancomycin-resistant enterococcus in end-stage renal disease. *Am J Kidney Dis* 1998;32:415–8.
192. Snyderman DR, Bryan JA, London WT, et al. Transmission of hepatitis B associated with hemodialysis: role of malfunction (blood leaks) in dialysis machines. *J Infect Dis* 1976;134:562–70.
193. Favero MS, Bond WW. Chemical disinfection of medical and surgical materials. In: Block SS, ed. *Disinfection, sterilization, and preservation*, 5th ed. Philadelphia, PA: Lippincott, Williams & Wilkins, 2000: 881–917.
194. Olsen RJ, Lynch P, Coyle MB, Cummings J, Bokete T, Stamm WE. Examination gloves as barriers to hand contamination and clinical practice. *JAMA* 1993;270:350–3.
195. Garner JS and the Hospital Infection Control Practices Advisory Committee. Guideline for isolation precautions in hospitals. *Infect Control Hosp Epidemiol* 1996;17:53–80. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.
196. American Society of Health-System Pharmacists. *AHFS Drug Information* 1999. Bethesda, MD: American Society of Health-System Pharmacists, 1999:1298–9.
197. US Food and Drug Administration. *Medwatch: the FDA medical products reporting program*. 2000. Available on the Internet at <<http://www.fda.gov/medwatch/safety/2000/safety00.htm#epogen>>.
198. Moyer LA, Alter MJ, Favero MS. Hemodialysis-associated hepatitis B: revised recommendations for serologic screening. *Semin Dial* 1990;3:201–4.
199. CDC. Immunization of health-care workers: recommendations of the Advisory Committee on Immunization Practices (ACIP) and the Hospital Infection Control Practices Advisory Committee (HICPAC). *MMWR* 1997;46(No. RR-18):1–42.
200. CDC. Update: recommendations to prevent hepatitis B virus transmission—United States. *MMWR* 1995;44:574–5.
201. CDC. Recommendations for HIV testing services for inpatients and outpatients in acute-care hospital settings. *MMWR* 1993;42(No. RR-2):1–6.
202. CDC. Recommendations for preventing the spread of vancomycin resistance: recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC). *MMWR* 1995;44(No. RR-12):1–13.
203. Title 42: Public health; Chapter IV: Health Care Financing Administration, Department of Health and Human Services; Part 405: Federal health insurance for the aged and disabled; Sections: 405.2136, 405.2140, 405.2150, and 405.2161. 42 CFR 405 (1998).
204. Bolyard EA, Tablan OC, Williams WW, et al, and the Hospital Infection Control Practices Advisory Committee. Guideline for infection control in health care personnel, 1998. *Am J Infect Control* 1998;26:289–354. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.
205. Title 29: Labor; Part 1910: Occupational safety and health standards; Section: 1910.1030. 29 CFR 1910.1030 (2000).
206. Rangel MC, Coronado VG, Euler GL, Strikas RA. Vaccine recommendations for patients on chronic dialysis. *Semin Dial* 2000;13:101–7.

Suggested Readings

- **Cleaning, disinfection, sterilization, and monitoring of hemodialysis fluids and equipment.**

Favero MS, Tokars JI, Arduino MJ, Alter MJ. Nosocomial infections associated with hemodialysis. In: Mayhall CG, ed. Hospital epidemiology and infection control, 2nd ed. Philadelphia, PA: Lippincott, Williams & Wilkins, 1999:897–917.

Tokars JI, Alter MJ, Arduino MJ. Nosocomial infections in hemodialysis units: strategies for control. In: Owen WF, Pereira BJG, Sayegh MH, eds. Dialysis and transplantation: a companion to Brenner and Rector's THE KIDNEY. Philadelphia, PA: W.B. Saunders Company, 2000:337–57.

Association for the Advancement of Medical Instrumentation. AAMI standards and recommended practices, vol. 3: dialysis. Arlington, VA: Association for the Advancement of Medical Instrumentation, 1998.

- **General information on cleaning and disinfection.**

Favero MS, Bond WW. Chemical disinfection of medical and surgical materials. In: Block SS, ed. Disinfection, sterilization, and preservation, 5th ed. Philadelphia, PA: Lippincott, Williams & Wilkins, 2000:881–917.

CDC. Guideline for handwashing and hospital environmental control, 1985. Atlanta, GA: US Department of Health and Human Services, Public Health Service, CDC. Available on the Internet at <<http://www.cdc.gov/ncidod/hip/Guide/handwash.htm>>.

- **General information on vancomycin-resistant enterococci epidemiology and control in hospitals.**

CDC. Recommendations for preventing the spread of vancomycin resistance: recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC). MMWR 1995;44(No. RR-12):1–13. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.

- **Hepatitis C virus infection.**

CDC. Recommendations for prevention and control of hepatitis C virus (HCV) infection and HCV-related chronic disease. MMWR 1998;47(No. RR-19):1–33. Available on the Internet at <<http://www.cdc.gov/hepatitis>>.

- **Preventing infections in patients with central venous hemodialysis catheters.**

National Kidney Foundation. Dialysis outcomes quality initiative. Clinical practice guidelines. Am J Kidney Dis 1997;30(Suppl 3):S137–S240. Available on the Internet at <<http://www.kidney.org>>.

Pearson ML, Hierholzer WJ Jr, Garner JS, et al. Guideline for prevention of intravascular device-related infections: part I. Intravascular device-related infections: an overview. Am J Infect Control 1996;24:262–77. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.

- **Standard Precautions and infection control precautions for hospitalized patients.**
Garner JS and the Hospital Infection Control Practices Advisory Committee. Guideline for isolation precautions in hospitals. *Infect Control Hosp Epidemiol* 1996;17:53–80. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.
- **Summaries of outbreaks in hemodialysis units and recommendations to prevent similar outbreaks.**
Favero MS, Tokars JI, Arduino MJ, Alter MJ. Nosocomial infections associated with hemodialysis. In: Mayhall CG, ed. *Hospital epidemiology and infection control*, 2nd ed. Philadelphia, PA: Lippincott, Williams & Wilkins, 1999:897–917.
Tokars JI, Alter MJ, Arduino MJ. Nosocomial infections in hemodialysis units: strategies for control. In: Owen WF, Pereira BJJ, Sayegh MH, eds. *Dialysis and transplantation: a companion to Brenner and Rector's THE KIDNEY*. Philadelphia, PA: W.B. Saunders Company, 2000:337–57.
- **Tuberculosis skin testing and treatment of patients with active disease.**
CDC. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. *MMWR* 1994;43(No. RR-13):1–32. Available on the Internet at <<http://www.cdc.gov/mmwr/preview/mmwrhtml/00035909.htm>>.
Tokars JI, Miller B. Tuberculin skin testing of ESRD patients [Letter]. *Am J Kidney Dis* 1997;30:456–7.
- **Vaccination and other health-care worker topics.**
CDC. Immunization of health-care workers: recommendations of the Advisory Committee on Immunization Practices (ACIP) and the Hospital Infection Control Practices Advisory Committee (HICPAC). *MMWR* 1997;46(No. RR-18):1–42. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.
Bolyard EA, Tablan OC, Williams WW, et al, and the Hospital Infection Control Practices Advisory Committee. Guideline for infection control in health care personnel, 1998. *Am J Infect Control* 1998;26:289–354. Available on the Internet at <<http://www.cdc.gov/ncidod/hip>>.
- **Vascular access skin site preparation and aseptic technique.**
National Kidney Foundation. Dialysis outcomes quality initiative. Clinical practice guidelines. *Am J Kidney Dis* 1997;30(Suppl 3):S137–S240. Available on the Internet at <<http://www.kidney.org>>.

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**Recommendations for Preventing Transmission of Infections
Among Chronic Hemodialysis Patients**

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GOAL AND OBJECTIVES

This *MMWR* provides recommendations regarding the prevention of bloodborne virus and bacterial infections in hemodialysis settings. These recommendations were prepared by CDC staff members after consultation with staff members from other federal agencies and specialists in the field. The goal of this report is to serve as a resource for health-care professionals, public health officials, and organizations involved in the care of patients receiving hemodialysis. Upon completion of this continuing education activity, the reader should be able to describe the recommendations for a) preventing bloodborne virus infections in hemodialysis settings, b) preventing bacterial infections in hemodialysis settings, c) developing and maintaining surveillance systems for infections and other adverse events, and d) developing training and education programs.

To receive continuing education credit, please answer all of the following questions.

1. **A comprehensive infection control program in a dialysis setting should include which of the following components? (Indicate all that apply.)**
 - A. Routine serologic testing for hepatitis B virus (HBV) and hepatitis C virus (HCV) infection.
 - B. Vaccination of susceptible patients against hepatitis B.
 - C. Surveillance for infections and other adverse events.
 - D. Infection control training and education.
 - E. Isolation of patients who test positive for hepatitis B surface antigen (HBsAg).

2. **Which of the following statements regarding hepatitis B vaccination in the dialysis setting are true? (Indicate all that apply.)**
 - A. Hepatitis B vaccine is recommended for all susceptible chronic hemodialysis patients.
 - B. Hepatitis B vaccine is recommended for all susceptible staff members.
 - C. All vaccinees should be tested 1–2 months after completion of the series to determine their response to the vaccine.
 - D. Nonresponders should be given an additional three doses of vaccine and retested.

3. **How should chronic dialysis patients who respond to hepatitis B vaccine be followed?**
 - A. No follow-up is necessary.
 - B. Give a booster dose of vaccine annually.
 - C. Test for antibody to HBsAg (anti-HBs) annually and give a booster dose of vaccine if anti-HBs is <10 milli-International Units (mIU)/mL.
 - D. Test for anti-HBs annually, give a booster dose of vaccine if anti-HBs is <10 mIU/ml, and retest for anti-HBs 1–2 months after booster.

4. **Which of the following statements regarding the management of HBsAg-positive patients are true? (Indicate all that apply.)**
 - A. HBsAg-positive patients do not have to be isolated from HBV-susceptible patients.
 - B. HBV-immune patients can act as a geographic buffer between HBsAg-positive and HBV-susceptible patients.
 - C. Dedicated equipment should be used for HBsAg-positive patients.
 - D. Staff members who are caring for HBsAg-positive patients can also care for HBV-susceptible patients at the same time.
 - E. Dialyzers should not be reused on HBsAg-positive patients.

5. **Which of the following statements regarding the management of HCV-positive patients are true?**
- A. HCV-positive patients do not have to be isolated from HCV-susceptible patients.
 - B. Staff members who are caring for HCV-positive patients can also care for HCV-negative patients at the same time.
 - C. Dialyzers can be reused on HCV-positive patients.
 - D. All of the above.
 - E. None of the above.
6. **From an infection control standpoint, what is the best way to deliver medications to dialysis patients?**
- A. Deliver medications separately to each patient.
 - B. Use a medication cart to deliver medications to each patient.
 - C. Prepare all medications at each patient's dialysis station and return unused supplies to a common area so they can be used for other patients.
 - D. None of the above.
7. **How should dialysis patients infected or colonized with methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci be treated in the dialysis unit?**
- A. No additional precautions are necessary.
 - B. Contact precautions should always be followed.
 - C. Dedicated equipment should be used.
 - D. If a patient has an infected skin wound with drainage that is not contained by dressings, fecal incontinence, or diarrhea uncontrolled with personal hygiene measures, staff members treating the patient should wear a separate gown and dialyze the patient as far away from other patients as possible.
8. **Which of the following statements are true regarding instruments and supplies that are taken to the patient's dialysis station but not used?**
- A. They can be returned to the clean supply area for use on other patients.
 - B. They must be disposed of or cleaned and disinfected before use on another patient.
 - C. They can be used for another patient if not visibly soiled.
 - D. They can be kept at that dialysis station for use on the next patient.
9. **Which of the following statements are true regarding hand washing?**
- A. Use of a waterless antiseptic hand rub can always be substituted for hand washing.
 - B. Use of a waterless antiseptic hand rub can never be substituted for hand washing.
 - C. Use of a waterless antiseptic hand rub can be substituted for hand washing only if no drug-resistant pathogens are present in the unit.
 - D. Use of a waterless antiseptic hand rub can be substituted for hand washing if hands are not visibly soiled.
10. **Indicate your work setting.**
- A. State/local health department.
 - B. Other public health setting.
 - C. Hospital clinic/private practice.
 - D. Managed care organization.
 - E. Academic institution.
 - F. Other.

- 11. Which best describes your professional activities?**
- A. Hemodialysis patient care/technical support/administration.
 - B. Nephrologist.
 - C. Infection control.
 - D. Laboratory/pharmacy.
 - E. Public health.
 - F. Other.
- 12. I plan to use these recommendations as the basis for . . . (Indicate all that apply.)**
- A. health education materials.
 - B. insurance reimbursement policies.
 - C. local practice guidelines.
 - D. public policy.
 - E. other.
- 13. Each month, approximately how many hemodialysis patients do you or your center treat?**
- A. None.
 - B. 1-5.
 - C. 6-20.
 - D. 21-50.
 - E. 50-100.
 - F. >100.
- 14. How much time did you spend reading this report and completing the exam?**
- A. 1-1.5 hours.
 - B. More than 1.5 hours but fewer than 2 hours.
 - C. 2-2.5 hours.
 - D. More than 2.5 hours.
- 15. After reading this report, I am confident I can describe the recommendations for preventing bloodborne virus infections in hemodialysis settings.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.
- 16. After reading this report, I am confident I can describe the recommendations for preventing bacterial infections in hemodialysis settings.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.

17. **After reading this report, I am confident I can describe the recommendations for developing and maintaining surveillance systems for infections and other adverse events.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.
18. **After reading this report, I am confident I can describe the recommendations for developing training and education programs.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.
19. **The objectives are relevant to the goals of this report.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.
20. **The tables and figure are useful.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.
21. **Overall, the presentation of the report enhanced my ability to understand the material.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.
22. **These recommendations will affect my practice.**
- A. Strongly agree.
 - B. Agree.
 - C. Neither agree nor disagree.
 - D. Disagree.
 - E. Strongly disagree.

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- A. Internet.
- B. Advertisement (e.g., fact sheet, *MMWR* cover, newsletter, or journal).
- C. Coworker/supervisor.
- D. Conference presentation.
- E. *MMWR* subscription.
- F. Other.

Correct answers for questions 1-9.
1. A, B, C, D, E; 2. A, B, C, D; 3. C; 4. B, C, E; 5. D; 6. A; 7. D; 8. B; 9. D.

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**Recommendations for Preventing Transmission of Infections
Among Chronic Hemodialysis Patients**

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| 12. <input type="checkbox"/> A <input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D <input type="checkbox"/> E | |

Signature	Date I Completed Exam
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Guidelines for the Prevention of Intravascular Catheter-Related Infections

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Guidelines for the Prevention of Intravascular Catheter-Related Infections

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Summary

These guidelines have been developed for practitioners who insert catheters and for persons responsible for surveillance and control of infections in hospital, outpatient, and home health-care settings. This report was prepared by a working group comprising members from professional organizations representing the disciplines of critical care medicine, infectious diseases, health-care infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatric medicine, and nursing. The working group was led by the Society of Critical Care Medicine (SCCM), in collaboration with the Infectious Disease Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), Surgical Infection Society (SIS), American College of Chest Physicians (ACCP), American Thoracic Society (ATS), American Society of Critical Care Anesthesiologists (ASCCA), Association for Professionals in Infection Control and Epidemiology (APIC), Infusion Nurses Society (INS), Oncology Nursing Society (ONS), Society of Cardiovascular and Interventional Radiology (SCVIR), American Academy of Pediatrics (AAP), and the Healthcare Infection Control Practices Advisory Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC) and is intended to replace the Guideline for Prevention of Intravascular Device-Related Infections published in 1996. These guidelines are intended to provide evidence-based recommendations for preventing catheter-related infections. Major areas of emphasis include 1) educating and training health-care providers who insert and maintain catheters; 2) using maximal sterile barrier precautions during central venous catheter insertion; 3) using a 2% chlorhexidine preparation for skin antisepsis; 4) avoiding routine replacement of central venous catheters as a strategy to prevent infection; and 5) using antiseptic/antibiotic impregnated short-term central venous catheters if the rate of infection is high despite adherence to other strategies (i.e., education and training, maximal sterile barrier precautions, and 2% chlorhexidine for skin antisepsis). These guidelines also identify performance indicators that can be used locally by health-care institutions or organizations to monitor their success in implementing these evidence-based recommendations.

Introduction

This report provides health-care practitioners with background information and specific recommendations to reduce the incidence of intravascular catheter-related bloodstream

The material in this report was prepared for publication by the National Center for Infectious Diseases, James M. Hughes, M.D., Director; Division of Healthcare Quality Promotion, Steven L. Solomon, M.D., Acting Director.

infections (CRBSI). These guidelines replace the *Guideline for Prevention of Intravascular Device-Related Infections*, which was published in 1996 (1).

The *Guidelines for the Prevention of Intravascular Catheter-Related Infections* have been developed for practitioners who insert catheters and for persons who are responsible for surveillance and control of infections in hospital, outpatient, and home health-care settings. This report was prepared by a working group composed of professionals representing the disciplines of critical care medicine, infectious diseases, health-care infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatrics, and nursing. The working group was led by the Society of Critical Care Medicine (SCCM), in collaboration with Infectious Disease Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), Surgical Infection Society (SIS), American College of Chest Physicians (ACCP), American Thoracic Society (ATS), American Society of Critical Care Anesthesiologists (ASCCA), Association for Professionals in Infection Control and Epidemiology (APIC), Infusion Nurses Society (INS), Oncology Nursing Society (ONS), Society of Cardiovascular and Interventional Radiology (SCVIR), American Academy of Pediatrics (AAP), and the Healthcare Infection Control Practices Advisory Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC). The recommendations presented in this report reflect consensus of HICPAC and other professional organizations.

Intravascular Catheter-Related Infections in Adult and Pediatric Patients: An Overview

Background

Intravascular catheters are indispensable in modern-day medical practice, particularly in intensive care units (ICUs). Although such catheters provide necessary vascular access, their use puts patients at risk for local and systemic infectious complications, including local site infection, CRBSI, septic thrombophlebitis, endocarditis, and other metastatic infections (e.g., lung abscess, brain abscess, osteomyelitis, and endophthalmitis).

Health-care institutions purchase millions of intravascular catheters each year. The incidence of CRBSI varies considerably by type of catheter, frequency of catheter manipulation, and patient-related factors (e.g., underlying disease and acuity of illness). Peripheral venous catheters are the devices most frequently used for vascular access. Although the incidence of local or bloodstream infections (BSIs) associated with peripheral venous catheters is usually low, serious infectious complications produce considerable annual morbidity because of the

frequency with which such catheters are used. However, the majority of serious catheter-related infections are associated with central venous catheters (CVCs), especially those that are placed in patients in ICUs. In the ICU setting, the incidence of infection is often higher than in the less acute in-patient or ambulatory setting. In the ICU, central venous access might be needed for extended periods of time; patients can be colonized with hospital-acquired organisms; and the catheter can be manipulated multiple times per day for the administration of fluids, drugs, and blood products. Moreover, some catheters can be inserted in urgent situations, during which optimal attention to aseptic technique might not be feasible. Certain catheters (e.g., pulmonary artery catheters and peripheral arterial catheters) can be accessed multiple times per day for hemodynamic measurements or to obtain samples for laboratory analysis, augmenting the potential for contamination and subsequent clinical infection.

The magnitude of the potential for CVCs to cause morbidity and mortality resulting from infectious complications has been estimated in several studies (2). In the United States, 15 million CVC days (i.e., the total number of days of exposure to CVCs by all patients in the selected population during the selected time period) occur in ICUs each year (2). If the average rate of CVC-associated BSIs is 5.3 per 1,000 catheter days in the ICU (3), approximately 80,000 CVC-associated BSIs occur in ICUs each year in the United States. The attributable mortality for these BSIs has ranged from no increase in mortality in studies that controlled for severity of illness (4–6), to 35% increase in mortality in prospective studies that did not use this control (7,8). Thus, the attributable mortality remains unclear. The attributable cost per infection is an estimated \$34,508–\$56,000 (5,9), and the annual cost of caring for patients with CVC-associated BSIs ranges from \$296 million to \$2.3 billion (10).

A total of 250,000 cases of CVC-associated BSIs have been estimated to occur annually if entire hospitals are assessed rather than ICUs exclusively (11). In this case, attributable mortality is an estimated 12%–25% for each infection, and the marginal cost to the health-care system is \$25,000 per episode (11).

Therefore, by several analyses, the cost of CVC-associated BSI is substantial, both in terms of morbidity and in terms of financial resources expended. To improve patient outcome and reduce health-care costs, strategies should be implemented to reduce the incidence of these infections. This effort should be multidisciplinary, involving health-care professionals who insert and maintain intravascular catheters, health-care managers who allocate resources, and patients who are capable of assisting in the care of their catheters. Although several individual strategies have been studied and shown to be effective in reducing CRBSI, studies using multiple strategies have not

been conducted. Thus, it is not known whether implementing multiple strategies will have an additive effect in reducing CRBSI, but it is logical to use multiple strategies concomitantly.

Terminology and Estimates of Risk

The terminology used to identify different types of catheters is confusing, because many clinicians and researchers use different aspects of the catheter for informal reference. A catheter can be designated by the type of vessel it occupies (e.g., peripheral venous, central venous, or arterial); its intended life span (e.g., temporary or short-term versus permanent or long-term); its site of insertion (e.g., subclavian, femoral, internal jugular, peripheral, and peripherally inserted central catheter [PICC]); its pathway from skin to vessel (e.g., tunneled versus nontunneled); its physical length (e.g., long versus short); or some special characteristic of the catheter (e.g., presence or absence of a cuff, impregnation with heparin, antibiotics or antiseptics, and the number of lumens). To

accurately define a specific type of catheter, all of these aspects should be described (Table 1).

The rate of all catheter-related infections (including local infections and systemic infections) is difficult to determine. Although CRBSI is an ideal parameter because it represents the most serious form of catheter-related infection, the rate of such infection depends on how CRBSI is defined.

Health-care professionals should recognize the difference between surveillance definitions and clinical definitions. The surveillance definitions for catheter-associated BSI includes all BSIs that occur in patients with CVCs, when other sites of infection have been excluded (Appendix A). That is, the surveillance definition overestimates the true incidence of CRBSI because not all BSIs originate from a catheter. Some bacteremias are secondary BSIs from undocumented sources (e.g., postoperative surgical sites, intra-abdominal infections, and hospital-associated pneumonia or urinary tract infections). Thus, surveillance definitions are really definitions for

TABLE 1. Catheters used for venous and arterial access

Catheter type	Entry site	Length	Comments
Peripheral venous catheters (short)	Usually inserted in veins of forearm or hand	<3 inches; rarely associated with bloodstream infection	Phlebitis with prolonged use; rarely associated with bloodstream infection
Peripheral arterial catheters	Usually inserted in radial artery; can be placed in femoral, axillary, brachial, posterior tibial arteries	<3 inches; associated with bloodstream infection	Low infection risk; rarely associated with bloodstream infection
Midline catheters	Inserted via the antecubital fossa into the proximal basilic or cephalic veins; does not enter central veins, peripheral catheters	3 to 8 inches	Anaphylactoid reactions have been reported with catheters made of elastomeric hydrogel; lower rates of phlebitis than short peripheral catheters
Nontunneled central venous catheters	Percutaneously inserted into central veins (subclavian, internal jugular, or femoral)	≥8 cm depending on patient size	Account for majority of CRBSI
Pulmonary artery catheters	Inserted through a Teflon® introducer in a central vein (subclavian, internal jugular, or femoral)	≥30 cm depending on patient size	Usually heparin bonded; similar rates of bloodstream infection as CVCs; subclavian site preferred to reduce infection risk
Peripherally inserted central venous catheters (PICC)	Inserted into basilic, cephalic, or brachial veins and enter the superior vena cava	≥20 cm depending on patient size	Lower rate of infection than nontunneled CVCs
Tunneled central venous catheters	Implanted into subclavian, internal jugular, or femoral veins	≥8 cm depending on patient size	Cuff inhibits migration of organisms into catheter tract; lower rate of infection than nontunneled CVC
Totally implantable	Tunneled beneath skin and have subcutaneous port accessed with a needle; implanted in subclavian or internal jugular vein	≥8 cm depending on patient size	Lowest risk for CRBSI; improved patient self-image; no need for local catheter-site care; surgery required for catheter removal
Umbilical catheters	Inserted into either umbilical vein or umbilical artery	≤6 cm depending on patient size	Risk for CRBSI similar with catheters placed in umbilical vein versus artery

catheter-associated BSIs. A more rigorous definition might include only those BSIs for which other sources were excluded by careful examination of the patient record, and where a culture of the catheter tip demonstrated substantial colonies of an organism identical to those found in the bloodstream. Such a clinical definition would focus on catheter-related BSIs. Therefore, to accurately compare a health-care facility's infection rate to published data, comparable definitions also should be used.

CDC and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) recommend that the rate of catheter-associated BSIs be expressed as the number of catheter-associated BSIs per 1,000 CVC days (12,13). This parameter is more useful than the rate expressed as the number of catheter-associated infections per 100 catheters (or percentage of catheters studied), because it accounts for BSIs over time and therefore adjusts risk for the number of days the catheter is in use.

Epidemiology and Microbiology

Since 1970, CDC's National Nosocomial Infection Surveillance System (NNIS) has been collecting data on the incidence and etiologies of hospital-acquired infections, including CVC-associated BSIs in a group of nearly 300 U.S. hospitals. The majority of hospital-acquired BSIs are associated with the use of a CVC, with BSI rates being substantially higher among patients with CVCs than among those without CVCs. Rates of CVC-associated BSI vary considerably by hospital size, hospital service/unit, and type of CVC. During 1992–2001, NNIS hospitals reported ICU rates of CVC-associated BSI ranging from 2.9 (in a cardiothoracic ICU) to 11.3 (in a neonatal nursery for infants weighing <1,000 g) BSIs per 1,000 CVC days (Table 2) (14).

The relative risk of catheter-associated BSI also has been assessed in a meta-analysis of 223 prospective studies of adult patients (11). Relative risk of infection was best determined by analyzing rates of infection both by BSIs per 100 catheters and BSIs per 1,000 catheter days. These rates, and the NNIS-derived data, can be used as benchmarks by individual hospitals to estimate how their rates compare with other institutions. Rates are influenced by patient-related parameters, such as severity of illness and type of illness (e.g., third-degree burns versus postcardiac surgery), and by catheter-related parameters, such as the condition under which the catheter was placed (e.g., elective versus urgent) and catheter type (e.g., tunneled versus nontunneled or subclavian versus jugular).

Types of organisms that most commonly cause hospital-acquired BSIs change over time. During 1986–1989, coagulase-negative staphylococci, followed by *Staphylococcus aureus*, were the most frequently reported causes of BSIs, accounting for

TABLE 2. Pooled means of the distribution of central venous catheter-associated bloodstream infection rates in hospitals reporting to the National Nosocomial Infection Surveillance System, January 1992–June 2001 (issued August 2001)

Type of intensive care unit	No.	Catheter days	Pool mean/1,000 catheter-days
Coronary	102	252,325	4.5
Cardiothoracic	64	419,674	2.9
Medical	135	671,632	5.9
Medical/surgical			
Major teaching	123	579,704	5.3
All others	180	863,757	3.8
Neurosurgical	47	123,780	4.7
Nursery, high risk (HRN)			
<1,000 g	138	438,261	11.3
1,001–1,500 g	136	213,351	6.9
1,501–2,500 g	132	163,697	4.0
>2,500 g	133	231,573	3.8
Pediatric	74	291,831	7.6
Surgical	153	900,948	5.3
Trauma	25	116,709	7.9
Burn	18	43,196	9.7
Respiratory	7	21,265	3.4

27% and 16% of BSIs, respectively (Table 3) (15). Pooled data from 1992 through 1999 indicate that coagulase-negative staphylococci, followed by enterococci, are now the most frequently isolated causes of hospital-acquired BSIs (12). Coagulase-negative staphylococci account for 37% (12) and *S. aureus* account for 12.6% of reported hospital-acquired BSIs (12). Also notable was the susceptibility pattern of *S. aureus* isolates. In 1999, for the first time since NNIS has been reporting susceptibilities, >50% of all *S. aureus* isolates from ICUs were resistant to oxacillin (12).

In 1999, enterococci accounted for 13.5% of BSIs, an increase from 8% reported to NNIS during 1986–1989. The percentage of enterococcal ICU isolates resistant to vancomycin also is increasing, escalating from 0.5% in 1989 to 25.9% in 1999 (12).

Candida spp. caused 8% of hospital-acquired BSIs reported to NNIS during 1986–1989 (15,16), and during 1992–1999 (12,17,18). Resistance of *Candida* spp. to commonly used

TABLE 3. Most common pathogens isolated from hospital acquired bloodstream infections

Pathogen	1986–1989 (%)	1992–1999 (%)
Coagulase-negative staphylococci	27	37
<i>Staphylococcus aureus</i>	16	13
Enterococcus	8	13
Gram-negative rods	19	14
<i>Escherichia coli</i>	6	2
<i>Enterobacter</i>	5	5
<i>Pseudomonas aeruginosa</i>	4	4
<i>Klebsiella pneumoniae</i>	4	3
<i>Candida</i> spp.	8	8

antifungal agents is increasing. Although NNIS has not reported the percentage of BSIs caused by nonalbicans species or fluconazole susceptibility data, other epidemiologic and clinical data document that fluconazole resistance is an increasingly relevant consideration when designing empiric therapeutic regimens for CRBSIs caused by yeast. Data from the Surveillance and Control of Pathogens of Epidemiologic Importance (SCOPE) Program documented that 10% of *C. albicans* bloodstream isolates from hospitalized patients were resistant to fluconazole (17). Additionally, 48% of *Candida* BSIs were caused by nonalbicans species, including *C. glabrata* and *C. krusei*, which are more likely than *C. albicans* to demonstrate resistance to fluconazole and itraconazole (18,19).

Gram-negative bacilli accounted for 19% of catheter-associated BSIs during 1986–1989 (15) compared with 14% of catheter-associated BSIs during 1992–1999 (12). An increasing percentage of ICU-related isolates are caused by *Enterobacteriaceae* that produce extended-spectrum β -lactamases (ESBLs), particularly *Klebsiella pneumoniae* (20). Such organisms not only are resistant to extended-spectrum cephalosporins, but also to frequently used, broad spectrum antimicrobial agents.

Pathogenesis

Migration of skin organisms at the insertion site into the cutaneous catheter tract with colonization of the catheter tip is the most common route of infection for peripherally inserted, short-term catheters (21,22). Contamination of the catheter hub contributes substantially to intraluminal colonization of long-term catheters (23–25). Occasionally, catheters might become hematogenously seeded from another focus of infection. Rarely, infusate contamination leads to CRBSI (26).

Important pathogenic determinants of catheter-related infection are 1) the material of which the device is made and 2) the intrinsic virulence factors of the infecting organism. In vitro studies demonstrate that catheters made of polyvinyl chloride or polyethylene are likely less resistant to the adherence of microorganisms than are catheters made of Teflon[®], silicone elastomer, or polyurethane (27,28). Therefore, the majority of catheters sold in the United States are no longer made of polyvinyl chloride or polyethylene. Some catheter materials also have surface irregularities that enhance the microbial adherence of certain species (e.g., coagulase-negative staphylococci, *Acinetobacter calcoaceticus*, and *Pseudomonas aeruginosa*) (29–31); catheters made of these materials are especially vulnerable to microbial colonization and subsequent infection. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also might predispose to catheter colonization and catheter-related

infection (31,32). This association has led to emphasis on preventing catheter-related thrombus as an additional mechanism for reducing CRBSI.

The adherence properties of a given microorganism also are important in the pathogenesis of catheter-related infection. For example, *S. aureus* can adhere to host proteins (e.g., fibronectin) commonly present on catheters (33,34). Also, coagulase-negative staphylococci adhere to polymer surfaces more readily than do other pathogens (e.g., *Escherichia coli* or *S. aureus*). Additionally, certain strains of coagulase-negative staphylococci produce an extracellular polysaccharide often referred to as “slime” (35,36). In the presence of catheters, this slime potentiates the pathogenicity of coagulase-negative staphylococci by allowing them to withstand host defense mechanisms (e.g., acting as a barrier to engulfment and killing by polymorphonuclear leukocytes) or by making them less susceptible to antimicrobial agents (e.g., forming a matrix that binds antimicrobials before their contact with the organism cell wall) (37). Certain *Candida* spp., in the presence of glucose-containing fluids, might produce slime similar to that of their bacterial counterparts, potentially explaining the increased proportion of BSIs caused by fungal pathogens among patients receiving parenteral nutrition fluids (38).

Strategies for Prevention of Catheter-Related Infections in Adult and Pediatric Patients

Quality Assurance and Continuing Education

Measures to minimize the risk for infection associated with intravascular therapy should strike a balance between patient safety and cost effectiveness. As knowledge, technology, and health-care settings change, infection control and prevention measures also should change. Well-organized programs that enable health-care providers to provide, monitor, and evaluate care and to become educated are critical to the success of this effort. Reports spanning the past two decades have consistently demonstrated that risk for infection declines following standardization of aseptic care (39–43), and that insertion and maintenance of intravascular catheters by inexperienced staff might increase the risk for catheter colonization and CRBSI (43,44). Specialized “IV teams” have shown unequivocal effectiveness in reducing the incidence of catheter-related infections and associated complications and costs (45–47). Additionally, infection risk increases with nursing staff reductions below a critical level (48).

Site of Catheter Insertion

The site at which a catheter is placed influences the subsequent risk for catheter-related infection and phlebitis. The influence of site on the risk for catheter infections is related in part to the risk for thrombophlebitis and density of local skin flora.

Phlebitis has long been recognized as a risk for infection. For adults, lower extremity insertion sites are associated with a higher risk for infection than are upper extremity sites (49–51). In addition, hand veins have a lower risk for phlebitis than do veins on the wrist or upper arm (52).

The density of skin flora at the catheter insertion site is a major risk factor for CRBSI. Authorities recommend that CVCs be placed in a subclavian site instead of a jugular or femoral site to reduce the risk for infection. No randomized trial satisfactorily has compared infection rates for catheters placed in jugular, subclavian, and femoral sites. Catheters inserted into an internal jugular vein have been associated with higher risk for infection than those inserted into a subclavian or femoral vein (22,53,54).

Femoral catheters have been demonstrated to have relatively high colonization rates when used in adults (55). Femoral catheters should be avoided, when possible, because they are associated with a higher risk for deep venous thrombosis than are internal jugular or subclavian catheters (56–60) and because of a presumption that such catheters are more likely to become infected. However, studies in pediatric patients have demonstrated that femoral catheters have a low incidence of mechanical complications and might have an equivalent infection rate to that of nonfemoral catheters (61–63). Thus, in adult patients, a subclavian site is preferred for infection control purposes, although other factors (e.g., the potential for mechanical complications, risk for subclavian vein stenosis, and catheter-operator skill) should be considered when deciding where to place the catheter. In a meta-analysis of eight studies, the use of bedside ultrasound for the placement of CVCs substantially reduced mechanical complications compared with the standard landmark placement technique (relative risk [RR] = 0.22; 95% confidence interval [CI] = 0.10–0.45) (64). Consideration of comfort, security, and maintenance of asepsis as well as patient-specific factors (e.g., preexisting catheters, anatomic deformity, and bleeding diathesis), relative risk of mechanical complications (e.g., bleeding and pneumothorax), the availability of bedside ultrasound, and the risk for infection should guide site selection.

Type of Catheter Material

Teflon[®] or polyurethane catheters have been associated with fewer infectious complications than catheters made of polyvinyl chloride or polyethylene (27,65,66). Steel needles used as an

alternative to catheters for peripheral venous access have the same rate of infectious complications as do Teflon[®] catheters (67,68). However, the use of steel needles frequently is complicated by infiltration of intravenous (IV) fluids into the subcutaneous tissues, a potentially serious complication if the infused fluid is a vesicant (68).

Hand Hygiene and Aseptic Technique

For short peripheral catheters, good hand hygiene before catheter insertion or maintenance, combined with proper aseptic technique during catheter manipulation, provides protection against infection. Good hand hygiene can be achieved through the use of either a waterless, alcohol-based product (69) or an antibacterial soap and water with adequate rinsing (70). Appropriate aseptic technique does not necessarily require sterile gloves; a new pair of disposable nonsterile gloves can be used in conjunction with a “no-touch” technique for the insertion of peripheral venous catheters. However, gloves are required by the Occupational Safety and Health Administration as standard precautions for the prevention of bloodborne pathogen exposure.

Compared with peripheral venous catheters, CVCs carry a substantially greater risk for infection; therefore, the level of barrier precautions needed to prevent infection during insertion of CVCs should be more stringent. Maximal sterile barrier precautions (e.g., cap, mask, sterile gown, sterile gloves, and large sterile drape) during the insertion of CVCs substantially reduces the incidence of CRBSI compared with standard precautions (e.g., sterile gloves and small drapes) (22,71). Although the efficacy of such precautions for insertion of PICCs and midline catheters has not been studied, the use of maximal barrier precautions also is probably applicable to PICCs.

Skin Antisepsis

In the United States, povidone iodine has been the most widely used antiseptic for cleansing arterial catheter and CVC-insertion sites (72). However, in one study, preparation of central venous and arterial sites with a 2% aqueous chlorhexidine gluconate lowered BSI rates compared with site preparation with 10% povidone-iodine or 70% alcohol (73). Commercially available products containing chlorhexidine have not been available until recently; in July 2000, the U.S. Food and Drug Administration (FDA) approved a 2% tincture of chlorhexidine preparation for skin antisepsis. Other preparations of chlorhexidine might not be as effective. Tincture of chlorhexidine gluconate 0.5% is no more effective in preventing CRBSI or CVC colonization than 10% povidone iodine, as demonstrated by a prospective, randomized study of adults

(74). However, in a study involving neonates, 0.5% chlorhexidine reduced peripheral IV colonization compared with povidone iodine (20/418 versus 38/408 catheters; $p = 0.01$) (75). This study, which did not include CVCs, had an insufficient number of participants to assess differences in BSI rates. A 1% tincture of chlorhexidine preparation is available in Canada and Australia, but not yet in the United States. No published trials have compared a 1% chlorhexidine preparation to povidone-iodine.

Catheter Site Dressing Regimens

Transparent, semipermeable polyurethane dressings have become a popular means of dressing catheter insertion sites. Transparent dressings reliably secure the device, permit continuous visual inspection of the catheter site, permit patients to bathe and shower without saturating the dressing, and require less frequent changes than do standard gauze and tape dressings; the use of these dressings saves personnel time.

In the largest controlled trial of dressing regimens on peripheral catheters, the infectious morbidity associated with the use of transparent dressings on approximately 2,000 peripheral catheters was examined (65). Data from this study suggest that the rate of colonization among catheters dressed with transparent dressings (5.7%) is comparable to that of those dressed with gauze (4.6%) and that no clinically substantial differences exist in either the incidences of catheter-site colonization or phlebitis. Furthermore, these data suggest that transparent dressings can be safely left on peripheral venous catheters for the duration of catheter insertion without increasing the risk for thrombophlebitis (65).

A meta-analysis has assessed studies that compared the risk for catheter-related BSIs for groups using transparent dressings versus groups using gauze dressing (76). The risk for CRBSIs did not differ between the groups. The choice of dressing can be a matter of preference. If blood is oozing from the catheter insertion site, gauze dressing might be preferred.

In a multi-center study, a chlorhexidine-impregnated sponge (Biopatch™) placed over the site of short-term arterial and CVCs reduced the risk for catheter colonization and CRBSI (77). No adverse systemic effects resulted from use of this device.

Catheter Securement Devices

Sutureless securement devices can be advantageous over suture in preventing catheter-related BSIs. One study, which involved only a limited number of patients and was underpowered, compared a sutureless device with suture for the securement of PICCS; in this study, CRBSI was reduced in the group of patients that received the sutureless device (78).

In-Line Filters

In-line filters reduce the incidence of infusion-related phlebitis (79,80). No data support their efficacy in preventing infections associated with intravascular catheters and infusion systems. Proponents of filters cite several potential benefits to using these filters, including 1) reducing the risk for infection from contaminated infusate or proximal contamination (i.e., introduced proximal to the filter); 2) reducing the risk for phlebitis in patients who require high doses of medication or in those in whom infusion-related phlebitis already has occurred; 3) removing particulate matter that might contaminate IV fluids (81); and 4) filtering endotoxin produced by gram-negative organisms in contaminated infusate (82). These theoretical advantages should be tempered by the knowledge that infusate-related BSI is rare and that filtration of medications or infusates in the pharmacy is a more practical and less costly way to remove the majority of particulates. Furthermore, in-line filters might become blocked, especially with certain solutions (e.g., dextran, lipids, and mannitol), thereby increasing the number of line manipulations and decreasing the availability of administered drugs (83). Thus, for reducing the risk for CRBSI, no strong recommendation can be made in favor of using in-line filters.

Antimicrobial/Antiseptic Impregnated Catheters and Cuffs

Certain catheters and cuffs that are coated or impregnated with antimicrobial or antiseptic agents can decrease the risk for CRBSI and potentially decrease hospital costs associated with treating CRBSIs, despite the additional acquisition cost of an antimicrobial/antiseptic impregnated catheter (84). All of the studies involving antimicrobial/antiseptic impregnated catheters have been conducted using triple-lumen, noncuffed catheters in adult patients whose catheters remained in place <30 days. Although all of the studies have been conducted in adults, these catheters have been approved by FDA for use in patients weighing ≥ 3 kg. No antiseptic or antimicrobial impregnated catheters currently are available for use in weighing <3 kg.

Chlorhexidine/Silver sulfadiazine. Catheters coated with chlorhexidine/silver sulfadiazine only on the external luminal surface have been studied as a means to reduce CRBSI. Two meta-analyses (2,85) demonstrated that such catheters reduced the risk for CRBSI compared with standard noncoated catheters. The mean duration of catheter placement in one meta-analysis ranged from 5.1 to 11.2 days (86). The half-life of antimicrobial activity against *S. epidermidis* is 3 days in vitro for catheters coated with chlorhexidine/silver sulfadiazine; this antimicrobial activity decreases over time (87). The benefit

for the patients who receive these catheters will be realized within the first 14 days (86). A second-generation catheter is now available with chlorhexidine coating both the internal and external luminal surfaces. The external surface has three times the amount of chlorhexidine and extended release of the surface bound antiseptics than that in the first generation catheters. The external surface coating of chlorhexidine is combined with silver-sulfadiazine, and the internal surface is coated with chlorhexidine alone. Preliminary studies indicate that prolonged anti-infective activity provides improved efficacy in preventing infections (88). Although rare, anaphylaxis has been reported with the use of these chlorhexidine/silver sulfadiazine catheters in Japan (89). Whether patients will become colonized or infected with organisms resistant to chlorhexidine/silver sulfadiazine has not been determined (86).

Chlorhexidine/silver sulfadiazine catheters are more expensive than standard catheters. However, one analysis has suggested that the use of chlorhexidine/silver sulfadiazine catheters should lead to a cost savings of \$68 to \$391 per catheter (90) in settings in which the risk for CRBSI is high despite adherence to other preventive strategies (e.g., maximal barrier precautions and aseptic techniques). Use of these catheters might be cost effective in ICU patients, burn patients, neutropenic patients, and other patient populations in which the rate of infection exceeds 3.3 per 1,000 catheter days (86).

Minocycline/Rifampin. In a multicenter randomized trial, CVCs impregnated on both the external and internal surfaces with minocycline/rifampin were associated with lower rates of CRBSI when compared with the first-generation chlorhexidine-silver sulfadiazine impregnated catheters (91). The beneficial effect began after day 6 of catheterization. None of the catheters were evaluated beyond 30 days. No minocycline/rifampin-resistant organisms were reported. However, *in vitro* data indicate that these impregnated catheters could increase the incidence of minocycline and rifampin resistance among pathogens, especially staphylococci. The half-life of antimicrobial activity against *S. epidermidis* is 25 days with catheters coated with minocycline/rifampin, compared with 3 days for the first-generation catheters coated with chlorhexidine/silver sulfadiazine *in vitro* (87). *In vivo*, the duration of antimicrobial activity of the minocycline/rifampin catheter is longer than that of the first-generation chlorhexidine/silver sulfadiazine catheter (91). No comparative studies have been published using the second-generation chlorhexidine/silver sulfadiazine catheter. Studies are needed to evaluate whether the improved performance of the minocycline/rifampin catheters results from the antimicrobial agents used or from the coating of both the internal and external surfaces. As with chlorhexidine/silver sulfadiazine catheters, some clinicians have recommended that the minocycline/rifampin catheters be

considered in patient populations when the rate of CRBSI exceeds 3.3 per 1,000 catheter days (86). Others suggest that reducing all rates of CRBSI should be the goal (92). The decision to use chlorhexidine/silver sulfadiazine or minocycline/rifampin impregnated catheters should be based on the need to enhance prevention of CRBSI after standard procedures have been implemented (e.g., educating personnel, using maximal sterile barrier precautions, and using 2% chlorhexidine skin antiseptics) and then balanced against the concern for emergence of resistant pathogens and the cost of implementing this strategy.

Platinum/Silver. Ionic metals have broad antimicrobial activity and are being used in catheters and cuffs to prevent CRBSI. A combination platinum/silver impregnated catheter is available in Europe and has recently been approved by FDA for use in the United States. Although these catheters are being marketed for their antimicrobial properties, no published studies have been presented to support an antimicrobial effect.

Silver cuffs. Ionic silver has been used in subcutaneous collagen cuffs attached to CVCs (93). The ionic silver provides antimicrobial activity and the cuff provides a mechanical barrier to the migration of microorganisms along the external surface of the catheter. In studies of catheters left in place >20 days, the cuff failed to reduce the incidence of CRBSI (94,95). Two other studies of short-term catheters could not demonstrate efficacy because of the minimal number of CRBSIs observed (93,96).

Systemic Antibiotic Prophylaxis

No studies have demonstrated that oral or parenteral antibacterial or antifungal drugs might reduce the incidence of CRBSI among adults (97–99). However, among low birth weight infants, two studies have assessed vancomycin prophylaxis; both demonstrated a reduction in CRBSI but no reduction in mortality (100,101). Because the prophylactic use of vancomycin is an independent risk factor for the acquisition of vancomycin-resistant enterococcus (VRE) (102), the risk for acquiring VRE likely outweighs the benefit of using prophylactic vancomycin.

Antibiotic/Antiseptic Ointments

Povidone-iodine ointment applied at the insertion site of hemodialysis catheters has been studied as a prophylactic intervention to reduce the incidence of catheter-related infections. One randomized study of 129 hemodialysis catheters demonstrated a reduction in the incidence of exit-site infections, catheter-tip colonization, and BSIs with the routine use of povidone-iodine ointment at the catheter insertion site compared with no ointment at the insertion site (103).

Several studies have evaluated the effectiveness of mupirocin ointment applied at the insertion sites of CVCs as a means to prevent CRBSI (104–106). Although mupirocin reduced the risk for CRBSI (106), mupirocin ointment also has been associated with mupirocin resistance (107,108), and might adversely affect the integrity of polyurethane catheters (109,110).

Nasal carriers of *S. aureus* have a higher risk for acquiring CRBSI than do noncarriers (103,111). Mupirocin ointment has been used intranasally to decrease nasal carriage of *S. aureus* and lessen the risk for CRBSI. However, resistance to mupirocin develops in both *S. aureus* and coagulase-negative staphylococci soon after routine use of mupirocin is instituted (107,108).

Other antibiotic ointments applied to the catheter insertion site also have been studied and have yielded conflicting results (112–114). In addition, rates of catheter colonization with *Candida* spp. might be increased with the use of antibiotic ointments that have no fungicidal activity (112,114). To avoid compromising the integrity of the catheter, any ointment that is applied to the catheter insertion site should be checked against the catheter and ointment manufacturers' recommendations regarding compatibility.

Antibiotic Lock Prophylaxis

To prevent CRBSI, antibiotic lock prophylaxis has been attempted by flushing and filling the lumen of the catheter with an antibiotic solution and leaving the solution to dwell in the lumen of the catheter. Three studies have demonstrated the usefulness of such prophylaxis in neutropenic patients with long-term catheters (115–117). In two of the studies, patients received either heparin alone (10 U/ml) or heparin plus 25 micrograms/ml of vancomycin. The third study compared vancomycin/ciprofloxacin/heparin (VCH) to vancomycin/heparin (VH) and then to heparin alone. The rate of CRBSI with vancomycin-susceptible organisms was significantly lower (VCH $p = 0.022$; VH $p = 0.028$) and the time to the first episode of bacteremia with vancomycin-susceptible organisms was substantially longer (VCH $p = 0.036$; VH $p = 0.011$) in patients receiving either vancomycin/ciprofloxacin/heparin or vancomycin/heparin compared with heparin alone (115–117). One study involving a limited number of children revealed no difference in rates of CRBSI between children receiving a heparin flush compared with those receiving heparin and vancomycin (118). However, because the use of vancomycin is an independent risk factor for the acquisition of VRE (102), this practice is not recommended routinely.

An anticoagulant/antimicrobial combination comprising minocycline and ethylenediaminetetraacetic acid (EDTA) has been proposed as a lock solution because it has antibiofilm

and antimicrobial activity against gram-positive, gram-negative, and *Candida* organisms (119), as well as anticoagulant properties. However, no controlled or randomized trials have demonstrated its efficacy.

Anticoagulants

Anticoagulant flush solutions are used widely to prevent catheter thrombosis. Because thrombi and fibrin deposits on catheters might serve as a nidus for microbial colonization of intravascular catheters (120,121), the use of anticoagulants might have a role in the prevention of CRBSI.

In a meta-analysis evaluating the benefit of heparin prophylaxis (3 U/ml in TPN, 5,000 U every 6 or 12 hours flush, or 2,500 U low molecular weight heparin subcutaneously) in patients with short-term CVCs, the risk for catheter-related central venous thrombosis was reduced with the use of prophylactic heparin (122). However, no substantial difference in the rate for CRBSI was observed. Because the majority of heparin solutions contain preservatives with antimicrobial activity, whether any decrease in the rate of CRBSI is a result of the reduced thrombus formation, the preservative, or both is unclear.

The majority of pulmonary artery, umbilical, and central venous catheters are available with a heparin-bonded coating. The majority are heparin-bonded with benzalkonium chloride, which provides the catheters with antimicrobial activity (123) and provides an anti-thrombotic effect (124).

Warfarin also has been evaluated as a means for reducing CRBSI by reducing thrombus formation on catheters (125,126). In patients with long-term CVCs, low-dose warfarin (i.e., 1 mg/day) reduced the incidence of catheter thrombus. No data demonstrate that warfarin reduces the incidence of CRBSI.

Replacement of Catheters

Peripheral Venous Catheters

Scheduled replacement of intravascular catheters has been proposed as a method to prevent phlebitis and catheter-related infections. Studies of short peripheral venous catheters indicate that the incidence of thrombophlebitis and bacterial colonization of catheters increases when catheters are left in place >72 hours (66,67,127). However, rates of phlebitis are not substantially different in peripheral catheters left in place 72 hours compared with 96 hours (128). Because phlebitis and catheter colonization have been associated with an increased risk for catheter-related infection, short peripheral catheter sites commonly are rotated at 72–96-hour intervals

to reduce both the risk for infection and patient discomfort associated with phlebitis.

Midline Catheters

Midline catheters have been associated with lower rates of phlebitis than short peripheral catheters and with lower rates of infection than CVCs (129–131). In one prospective study of 140 midline catheters, their use was associated with a BSI rate of 0.8 per 1,000 catheter-days (131). No specific risk factors, including duration of catheterization, were associated with infection. Midline catheters were in place a median of 7 days, but for as long as 49 days. Although the findings of this study suggested that midline catheters can be changed only when there is a specific indication, no prospective, randomized studies have assessed the benefit of routine replacement as a strategy to prevent CRBSI associated with midline catheters.

CVCs, Including PICCs and Hemodialysis Catheters

Catheter replacement at scheduled time intervals as a method to reduce CRBSI has not lowered rates. Two trials have assessed a strategy of changing the catheter every 7 days compared with a strategy of changing catheters as needed (132,133). One of these studies involved 112 surgical ICU patients needing CVCs, pulmonary artery catheters, or peripheral arterial catheters (132), whereas the other study involved only subclavian hemodialysis catheters (133). In both studies, no difference in CRBSI was observed in patients undergoing scheduled catheter replacement every 7 days compared with patients whose catheters were replaced as needed.

Scheduled guidewire exchanges of CVCs is another proposed strategy for preventing CRBSI. The results of a meta-analysis of 12 randomized controlled trials assessing CVC management failed to prove any reduction of CRBSI rates through routine replacement of CVCs by guidewire exchange compared with catheter replacement on an as-needed basis (134). Thus, routine replacement of CVCs is not necessary for catheters that are functioning and have no evidence of causing local or systemic complications.

Catheter replacement over a guidewire has become an accepted technique for replacing a malfunctioning catheter or exchanging a pulmonary artery catheter for a CVC when invasive monitoring no longer is needed. Catheter insertion over a guidewire is associated with less discomfort and a significantly lower rate of mechanical complications than are those percutaneously inserted at a new site (135); in addition, this technique provides a means of preserving limited venous access in some patients. Replacement of temporary catheters over a guidewire in the presence of bacteremia is not an

acceptable replacement strategy, because the source of infection is usually colonization of the skin tract from the insertion site to the vein (22,135). However, in selected patients with tunneled hemodialysis catheters and bacteremia, catheter exchange over a guidewire, in combination with antibiotic therapy, might be an alternative as a salvage strategy in patients with limited venous access (136–139).

Hemodialysis Catheters

The use of catheters for hemodialysis is the most common factor contributing to bacteremia in dialysis patients (140,141). The relative risk for bacteremia in patients with dialysis catheters is sevenfold the risk for patients with primary arteriovenous fistulas (142). Despite the National Kidney Foundation's effort to reduce the number of hemodialysis patients maintained with catheter access, catheter use increased from 12.7% in 1995 to 22.2% in 1999 (143). Rates for bacteremia per 100 patient months were 0.2 for arteriovenous fistulas, 0.5 for grafts, 5.0 for cuffed catheters, and 8.5 for noncuffed catheters (CDC, unpublished data, 1999).

To reduce the rate of infection, hemodialysis catheters should be avoided in favor of arteriovenous fistulas and grafts. If temporary access is needed for dialysis, a cuffed catheter is preferable to a noncuffed catheter, even in the ICU setting, if the catheter is expected to stay in place for >3 weeks (11,144).

Pulmonary Artery Catheters

Pulmonary artery catheters are inserted through a Teflon[®] introducer and typically remain in place an average of 3 days. The majority of pulmonary artery catheters are heparin bonded, which reduces not only catheter thrombosis but also microbial adherence to the catheter (145). Meta-analysis indicates that standard nonheparin-bonded pulmonary artery catheter rates of CRBSI are 5.5 per 1,000 catheter days; for heparin-bonded pulmonary artery catheters, this rate is 2.6 per 1,000 catheter days (11). Because the majority of pulmonary artery catheters are heparin-bonded, the relative risk of infection with these catheters is similar to that of CVC (2.6 versus 2.3 per 1,000 catheter days) (11).

A prospective study of 442 pulmonary artery catheters demonstrated an increased risk for CRBSI after 5 days (0/442 CRBSI before 5 days versus 5/442 CRBSI after 5 days; $p < 0.001$) (146). A prospective observational study of 71 pulmonary artery catheters demonstrated higher infection rates in catheters left in place longer than 7 days (2% before 7 days versus 16% after 7 days; $p = 0.056$) (147). However, no studies indicate that catheter replacement at scheduled time intervals is an effective method to reduce CRBSI (132,135). In patients who continue to require hemodynamic monitoring,

pulmonary artery catheters do not need to be changed more frequently than every 7 days. No specific recommendation can be made regarding routine replacement of catheters that need to be in place for >7 days.

Pulmonary artery catheters are usually packaged with a thin plastic sleeve that prevents touch contamination when placed over the catheter. In a study of 166 catheters, patients who were randomly assigned to have their catheters self-contained within this sleeve had a reduced risk for CRBSI compared with those who had a pulmonary artery catheter placed without the sleeve ($p = 0.002$) (148).

Peripheral Arterial Catheters

Peripheral arterial catheters are usually inserted into the radial or femoral artery and permit continuous blood pressure monitoring and blood gas measurements. The rate of CRBSI is comparable to that of temporary CVCs (2.9 versus 2.3 per 1,000 catheter days) (11). One study of peripheral arterial catheters demonstrated no difference in infection rates between changing catheters at scheduled times and changing arterial catheters on an as-needed basis (132). One observational study of 71 arterial catheters revealed that 10 local infections and four CRBSIs occurred in patients who had peripheral arterial catheters in place for >4 days compared with one local infection and no CRBSIs in patients whose catheters were in place ≤ 4 days ($p < 0.05$) (147). Because the risk for CRBSI is likely similar to that of short-term CVCs, arterial catheters can be approached in a similar way. No specific recommendation can be made regarding replacement of catheters that need to be in place for >5 days.

Replacement of Administration Sets

The optimal interval for routine replacement of IV administration sets has been examined in three well-controlled studies. Data from each of these studies reveal that replacing administration sets no more frequently than 72 hours after initiation of use is safe and cost-effective (149–151). Data from a more recent study demonstrated that rates of phlebitis were not substantially different if administration sets were left in place 96 hours compared with 72 hours (128). When a fluid that enhances microbial growth is infused (e.g., lipid emulsions and blood products), more frequent changes of administration sets are indicated, because these products have been identified as independent risk factors for CRBSI (152–158).

Stopcocks (used for injection of medications, administration of IV infusions, and collection of blood samples) represent a potential portal of entry for microorganisms into vascular access catheters and IV fluids. Stopcock contamination is common, occurring in 45% and 50% in the majority of series.

Whether such contamination is a substantial entry point of CRBSI has been difficult to prove.

“Piggyback” systems are used as an alternative to stopcocks. However, they also pose a risk for contamination of the intravascular fluid if the device entering the rubber membrane of an injection port is exposed to air or comes into direct contact with nonsterile tape used to fix the needle to the port. Modified piggyback systems have the potential to prevent contamination at these sites (159).

Needleless Intravascular Catheter Systems

Attempts to reduce the incidence of sharp injuries and the resultant risk for transmission of bloodborne infections to health-care workers have led to the design and introduction of needleless infusion systems. When the devices are used according to manufacturers’ recommendations, they do not substantially affect the incidence of CRBSI (160–167).

Multidose Parenteral Medication Vials

Parenteral medications commonly are dispensed in multidose, parenteral medication vials that might be used for prolonged periods for one or more patients. Although the overall risk for extrinsic contamination of multidose vials is likely minimal (168), the consequences of contamination might result in life-threatening infection (169,170). Single-use vials are frequently preservative-free and might pose a risk for contamination if they are punctured several times.

Special Considerations for Intravascular Catheter-Related Infections in Pediatric Patients

Prevention of CRBSI in children requires additional considerations, although only certain studies have been performed specifically in children. Pediatric data have been derived largely from studies in neonatal or pediatric ICUs and pediatric oncology patients.

Epidemiology

As in adults, the majority of BSIs in children are associated with the use of an intravascular catheter. From 1995 through 2000, the pooled mean catheter-associated BSI rate for all pediatric ICUs reporting data to NNIS was 7.7 per 1,000 catheter days (171,172). Umbilical catheter and CVC-associated BSI rates for neonatal ICUs ranged from 11.3 per 1,000 catheter days in children with birth weight <1,000 g to 4.0 per 1,000 catheter days in children whose birth weight was

>2,500 g (171). Catheter utilization rates were comparable in adult and pediatric ICUs (172,173).

Microbiology

As in adults, the majority of CRBSIs in children are caused by coagulase-negative staphylococci. During 1992–1999, these bacteria accounted for 37.7% of BSIs in pediatric ICUs reporting to NNIS (12). Exposure to lipids has been identified as an independent risk factor for development of coagulase-negative staphylococcal bacteremia in very low birth weight infants (i.e., those weighing <1,000 g) (odds ratio [OR] = 9.4; 95% CI = 1.2–74.2) (155), as well as candidemia in the neonatal ICU (OR = 5.33; 95% CI = 1.23–48.4) (154). Gram-negative bacteria accounted for 25% of BSIs reported in pediatric ICUs (172), whereas enterococci and *Candida* spp. accounted for 10% and 9%, respectively (172).

Peripheral Venous Catheters

As in adults, the use of peripheral venous catheters in pediatric patients might be complicated by phlebitis, infusion extravasation, and catheter infection (174). Catheter location, infusion of parenteral nutritional fluids with continuous IV lipid emulsions, and length of ICU stay before catheter insertion have all increased pediatric patients' risk for phlebitis. However, contrary to the risk in adults, the risk for phlebitis in children has not increased with the duration of catheterization (174,175).

Peripheral Arterial Catheters

In a prospective study of 340 peripheral arterial catheters in children, the following two risk factors for catheter-related infection were identified: 1) use of an arterial system that permitted backflow of blood into the pressure tubing and 2) duration of catheterization (176). Although a correlation was found between duration of arterial catheterization and risk for catheter colonization, the risk remained constant for 2–20 days at 6.2% (176).

Umbilical Catheters

Although the umbilical stump becomes heavily colonized soon after birth, umbilical-vessel catheterization often is used for vascular access in newborn infants. Umbilical vessels can be cannulated easily and permit both collection of blood samples and measurement of hemodynamic status. The incidences of catheter colonization and BSI are similar for umbilical vein catheters and umbilical artery catheters. In several studies, an estimated 40%–55% of umbilical artery catheters were colonized and 5% resulted in CRBSI; umbilical

vein catheters were associated with colonization in 22%–59% of cases (177–179) and with CRBSI in 3%–8% of cases (178). Although CRBSI rates are similar for umbilical catheters in the high position (i.e., above the diaphragm) compared with the low position (i.e., below the diaphragm and above the aortic bifurcation), catheters placed in the high position result in a lower incidence of vascular complications without an increase in adverse sequelae (178).

Risk factors for infection differ for umbilical artery and umbilical vein catheters. In one study, neonates with very low birth weight who also received antibiotics for ≥ 10 days were at increased risk for umbilical artery CRBSIs (178). In comparison, those with higher birth weight and receipt of parenteral nutrition fluids were at increased risk for umbilical vein CRBSI. Duration of catheterization was not an independent risk factor for infection of either type of umbilical catheter.

CVCs

Because of the limited vascular sites in children, attention should be given to the frequency with which catheters are replaced in these patients. In a study in which survival analysis techniques were used to examine the relation between the duration of central venous catheterization and complications in pediatric ICU patients, all of the patients studied ($n = 397$) remained uninfected for a median of 23.7 days (180). In addition, no relation was found between duration of catheterization and the daily probability of infection ($r = 0.21$; $p > 0.1$), suggesting that routine replacement of CVCs likely does not reduce the incidence of catheter-related infection (180).

Catheter Site Care

Although data regarding the use of the chlorhexidine-impregnated sponge (Biopatch™) in children are limited, one randomized, controlled study involving 705 neonates reported a substantial decrease in colonized catheter tips in infants in the Biopatch™ group compared with the group that had standard dressings (15% versus 24%; RR = 0.6; 95% CI = 0.5–0.9), but no difference in the rates of CRBSI or BSI without a source. Biopatch™ was associated with localized contact dermatitis in infants of very low birth weight. Of 98 neonates with very low birth weight, 15 (15%) developed localized contact dermatitis; four (1.5%) of 237 neonates weighing >1,000 g developed this reaction ($p < 0.0001$). Infants with gestational age <26 weeks who had CVCs placed at age ≤ 8 days were at increased risk for having localized contact dermatitis, whereas no infants in the control group developed this local reaction (181).

Performance Indicators

Performance indicators for reducing CRBSI are 1) implementation of educational programs that include didactic and interactive components for those who insert and maintain catheters; 2) use of maximal sterile barrier precautions during catheter placement; 3) use of chlorhexidine for skin antiseptics; and 4) rates of catheter discontinuation when the catheter is no longer essential for medical management. The impact these recommendations will have on individual institutions should be evaluated using specific performance indicators.

Recommendations for Placement of Intravascular Catheters in Adults and Children

These recommendations are designed to reduce the infectious complications associated with intravascular catheter use. Recommendations should be considered in the context of the institution's experience with catheter-related infections, experience with other adverse catheter-related complications (e.g., thrombosis, hemorrhage, and pneumothorax), and availability of personnel skilled in the placement of intravascular devices. Recommendations are provided for 1) intravascular-catheter use in general; 2) specific devices; and 3) special circumstances (i.e., intravascular-device use in pediatric patients and CVC use for parenteral nutrition and hemodialysis access). Recommendations regarding the frequency of replacing catheters, dressings, administration sets, and fluids also are provided (Appendix B).

As in previous guidelines issued by CDC and HICPAC, each recommendation is categorized on the basis of existing scientific data, theoretical rationale, applicability, and economic impact. The CDC/HICPAC system for categorizing recommendations is as follows:

Category IA. Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiologic studies.

Category IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies, and a strong theoretical rationale.

Category IC. Required by state or federal regulations, rules, or standards.

Category II. Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale.

Unresolved issue. Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists.

- I. Health-care worker education and training
 - A. Educate health-care workers regarding the indications for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection-control measures to prevent intravascular catheter-related infections (39,43,45–47,182–187). **Category IA**
 - B. Assess knowledge of and adherence to guidelines periodically for all persons who insert and manage intravascular catheters (39,43,46,182,188). **Category IA**
 - C. Ensure appropriate nursing staff levels in ICUs to minimize the incidence of CRBSIs (48,189,190). **Category IB**
- II. Surveillance
 - A. Monitor the catheter sites visually or by palpation through the intact dressing on a regular basis, depending on the clinical situation of individual patients. If patients have tenderness at the insertion site, fever without obvious source, or other manifestations suggesting local or BSI, the dressing should be removed to allow thorough examination of the site (1,191–193). **Category IB**
 - B. Encourage patients to report to their health-care provider any changes in their catheter site or any new discomfort. **Category II**
 - C. Record the operator, date, and time of catheter insertion and removal, and dressing changes on a standardized form. **Category II**
 - D. Do not routinely culture catheter tips (8,194,195). **Category IA**
- III. Hand hygiene
 - A. Observe proper hand-hygiene procedures either by washing hands with conventional antiseptic-containing soap and water or with waterless alcohol-based gels or foams. Observe hand hygiene before and after palpating catheter insertion sites, as well as before and after inserting, replacing, accessing, repairing, or dressing an intravascular catheter. Palpation of the insertion site should not be performed after the application of antiseptic, unless aseptic technique is maintained (43,70,196–200). **Category IA**
 - B. Use of gloves does not obviate the need for hand hygiene (43,198,199). **Category IA**
- IV. Aseptic technique during catheter insertion and care
 - A. Maintain aseptic technique for the insertion and care of intravascular catheters (22,71,201,202). **Category IA**

- B. Wear clean or sterile gloves when inserting an intravascular catheter as required by the Occupational Safety and Health Administration Bloodborne Pathogens Standard. **Category IC.** Wearing clean gloves rather than sterile gloves is acceptable for the insertion of peripheral intravascular catheters if the access site is not touched after the application of skin antiseptics. Sterile gloves should be worn for the insertion of arterial and central catheters (201,203). **Category IA**
- C. Wear clean or sterile gloves when changing the dressing on intravascular catheters. **Category IC**
- V. Catheter insertion
- Do not routinely use arterial or venous cutdown procedures as a method to insert catheters (204–206). **Category IA**
- VI. Catheter site care
- A. Cutaneous antiseptics
1. Disinfect clean skin with an appropriate antiseptic before catheter insertion and during dressing changes. Although a 2% chlorhexidine-based preparation is preferred, tincture of iodine, an iodophor, or 70% alcohol can be used (73,75,207,208). **Category IA**
 2. No recommendation can be made for the use of chlorhexidine in infants aged <2 months. **Unresolved issue**
 3. Allow the antiseptic to remain on the insertion site and to air dry before catheter insertion. Allow povidone iodine to remain on the skin for at least 2 minutes, or longer if it is not yet dry before insertion (73,75,207,208). **Category IB**
 4. Do not apply organic solvents (e.g., acetone and ether) to the skin before insertion of catheters or during dressing changes (209). **Category IA**
- VII. Catheter-site dressing regimens
- A. Use either sterile gauze or sterile, transparent, semi-permeable dressing to cover the catheter site (146,210–212). **Category IA**
- B. Tunneled CVC sites that are well healed might not require dressings. **Category II**
- C. If the patient is diaphoretic, or if the site is bleeding or oozing, a gauze dressing is preferable to a transparent, semi-permeable dressing (146,210–212). **Category II**
- D. Replace catheter-site dressing if the dressing becomes damp, loosened, or visibly soiled (146,210). **Category IB**
- E. Change dressings at least weekly for adult and adolescent patients depending on the circumstances of the individual patient (211). **Category II**
- F. Do not use topical antibiotic ointment or creams on insertion sites (except when using dialysis catheters) because of their potential to promote fungal infections and antimicrobial resistance (107,213). **Category IA** (See Central Venous Catheters, Including PICCs, Hemodialysis, and Pulmonary Artery Catheters, in Adult and Pediatric Patients, Section II.I.)
- G. Do not submerge the catheter under water. Show-ering should be permitted if precautions can be taken to reduce the likelihood of introducing organisms into the catheter (e.g., if the catheter and connecting device are protected with an impermeable cover during the shower (214,215). **Category II**
- VIII. Selection and replacement of intravascular catheters
- A. Select the catheter, insertion technique, and insertion site with the lowest risk for complications (infectious and noninfectious) for the anticipated type and duration of IV therapy (22,55,59,216–218). **Category IA**
- B. Promptly remove any intravascular catheter that is no longer essential (219,220). **Category IA**
- C. Do not routinely replace central venous or arterial catheters solely for the purposes of reducing the incidence of infection (134,135,221). **Category IB**
- D. Replace peripheral venous catheters at least every 72–96 hours in adults to prevent phlebitis (128). Leave peripheral venous catheters in place in children until IV therapy is completed, unless complications (e.g., phlebitis and infiltration) occur (174,175,222,223). **Category IB**
- E. When adherence to aseptic technique cannot be ensured (i.e., when catheters are inserted during a medical emergency), replace all catheters as soon as possible and after no longer than 48 hours (22,71,201,202). **Category II**
- F. Use clinical judgment to determine when to replace a catheter that could be a source of infection (e.g., do not routinely replace catheters in patients whose only indication of infection is fever). Do not routinely replace venous catheters in patients who are bacteremic or fungemic if the source of infection is unlikely to be the catheter (224). **Category II**
- G. Replace any short-term CVC if purulence is observed at the insertion site, which indicates infection (224,225). **Category IB**

- H. Replace all CVCs if the patient is hemodynamically unstable and CRBSI is suspected (224,225).
Category II
- I. Do not use guidewire techniques to replace catheters in patients suspected of having catheter-related infection (134,135). **Category IB**
- IX. Replacement of administration sets*, needleless systems, and parenteral fluids
- A. Administration sets
1. Replace administration sets, including secondary sets and add-on devices, no more frequently than at 72-hour intervals, unless catheter-related infection is suspected or documented (23, 149–151). **Category IA**
 2. Replace tubing used to administer blood, blood products, or lipid emulsions (those combined with amino acids and glucose in a 3-in-1 admixture or infused separately) within 24 hours of initiating the infusion (158,226–229). **Category IB.** If the solution contains only dextrose and amino acids, the administration set does not need to be replaced more frequently than every 72 hours (226). **Category II**
 3. Replace tubing used to administer propofol infusions every 6 or 12 hours, depending on its use, per the manufacturer's recommendation (230). **Category IA**
- B. Needleless intravascular devices
1. Change the needleless components at least as frequently as the administration set (160–162, 164–167). **Category II**
 2. Change caps no more frequently than every 72 hours or according to manufacturers' recommendations (160,162,165,166). **Category II**
 3. Ensure that all components of the system are compatible to minimize leaks and breaks in the system (163). **Category II**
 4. Minimize contamination risk by wiping the access port with an appropriate antiseptic and accessing the port only with sterile devices (162,163,165). **Category IB**
- C. Parenteral fluids
1. Complete the infusion of lipid-containing solutions (e.g., 3-in-1 solutions) within 24 hours of hanging the solution (156–158,226,229). **Category IB**
 2. Complete the infusion of lipid emulsions alone within 12 hours of hanging the emulsion. If volume considerations require more time, the infusion should be completed within 24 hours (156–158). **Category IB**
 3. Complete infusions of blood or other blood products within 4 hours of hanging the blood (231–234). **Category II**
 4. No recommendation can be made for the hang time of other parenteral fluids. **Unresolved issue**
- X. IV-injection ports
- A. Clean injection ports with 70% alcohol or an iodophor before accessing the system (164,235,236). **Category IA**
- B. Cap all stopcocks when not in use (235). **Category IB**
- XI. Preparation and quality control of IV admixtures
- A. Admix all routine parenteral fluids in the pharmacy in a laminar-flow hood using aseptic technique (237,238). **Category IB**
- B. Do not use any container of parenteral fluid that has visible turbidity, leaks, cracks, or particulate matter or if the manufacturer's expiration date has passed (237). **Category IB**
- C. Use single-dose vials for parenteral additives or medications when possible (237,239). **Category II**
- D. Do not combine the leftover content of single-use vials for later use (237,239). **Category IA**
- E. If multidose vials are used
1. Refrigerate multidose vials after they are opened if recommended by the manufacturer. **Category II**
 2. Cleanse the access diaphragm of multidose vials with 70% alcohol before inserting a device into the vial (236). **Category IA**
 3. Use a sterile device to access a multidose vial and avoid touch contamination of the device before penetrating the access diaphragm (235,240). **Category IA**
 4. Discard multidose vial if sterility is compromised (235,240). **Category IA**
- XII. In-line filters
Do not use filters routinely for infection-control purposes (80,241). **Category IA**
- XIII. IV-therapy personnel
Designate trained personnel for the insertion and maintenance of intravascular catheters (46,47,210,242). **Category IA**

*Administration sets include the area from the spike of tubing entering the fluid container to the hub of the vascular access device. However, a short extension tube might be connected to the catheter and might be considered a portion of the catheter to facilitate aseptic technique when changing administration sets.

XIV. Prophylactic antimicrobials

Do not administer intranasal or systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter to prevent catheter colonization or BSI (97,98,108,243). **Category IA**

Peripheral Venous Catheters, Including Midline Catheters, in Adult and Pediatric Patients

I. Selection of peripheral catheter

- A. Select catheters on the basis of the intended purpose and duration of use, known complications (e.g., phlebitis and infiltration), and experience of individual catheter operators (67,68,244). **Category IB**
- B. Avoid the use of steel needles for the administration of fluids and medication that might cause tissue necrosis if extravasation occurs (67,68). **Category IA**
- C. Use a midline catheter or PICC when the duration of IV therapy will likely exceed 6 days (244). **Category IB**

II. Selection of peripheral-catheter insertion site

- A. In adults, use an upper- instead of a lower-extremity site for catheter insertion. Replace a catheter inserted in a lower-extremity site to an upper-extremity site as soon as possible (67,245). **Category IA**
- B. In pediatric patients, the hand, the dorsum of the foot, or the scalp can be used as the catheter insertion site. **Category II**

C. Replacement of catheter

1. Evaluate the catheter insertion site daily, by palpation through the dressing to discern tenderness and by inspection if a transparent dressing is in use. Gauze and opaque dressings should not be removed if the patient has no clinical signs infection. If the patient has local tenderness or other signs of possible CRBSI, an opaque dressing should be removed and the site inspected visually. **Category II**
2. Remove peripheral venous catheters if the patient develops signs of phlebitis (e.g., warmth, tenderness, erythema, and palpable venous cord), infection, or a malfunctioning catheter (66). **Category IB**
3. In adults, replace short, peripheral venous catheters at least 72–96 hours to reduce the risk for phlebitis. If sites for venous access are limited and no evidence of phlebitis or infection is present, peripheral venous catheters can be left in place for longer periods, although the patient and the

insertion sites should be closely monitored (66,128,246). **Category IB**

4. Do not routinely replace midline catheters to reduce the risk for infection (131). **Category IB**
5. In pediatric patients, leave peripheral venous catheters in place until IV therapy is completed, unless a complication (e.g., phlebitis and infiltration) occurs (174,175,222,223). **Category IB**

III. Catheter and catheter-site care

Do not routinely apply prophylactic topical antimicrobial or antiseptic ointment or cream to the insertion site of peripheral venous catheters (107,213). **Category IA**

Central Venous Catheters, Including PICCs, Hemodialysis, and Pulmonary Artery Catheters, in Adult and Pediatric Patients

I. Surveillance

- A. Conduct surveillance in ICUs and other patient populations to determine CRBSI rates, monitor trends in those rates, and assist in identifying lapses in infection-control practices (3,12,16,247–250). **Category IA**
- B. Express ICU data as the number of catheter-associated BSIs per 1,000 catheter-days for both adults and children and stratify by birth weight categories for neonatal ICUs to facilitate comparisons with national data in comparable patient populations and health-care settings (3,12,16,247–250). **Category IB**
- C. Investigate events leading to unexpected life-threatening or fatal outcomes. This includes any process variation for which a recurrence would likely present an adverse outcome (13). **Category IC**

II. General principles

- A. Use a CVC with the minimum number of ports or lumens essential for the management of the patient (251–254). **Category IB**
- B. Use an antimicrobial or antiseptic-impregnated CVC in adults whose catheter is expected to remain in place >5 days if, after implementing a comprehensive strategy to reduce rates of CRBSI, the CRBSI rate remains above the goal set by the individual institution based on benchmark rates (Table 2) and local factors. The comprehensive strategy should include the following three components: educating persons who insert and maintain catheters, use of maximal sterile barrier precautions, and a 2% chlorhexidine preparation for skin antisepsis during CVC insertion (84–86,90,91,255). **Category IB**

- C. No recommendation can be made for the use of impregnated catheters in children. **Unresolved issue**
- D. Designate personnel who have been trained and exhibit competency in the insertion of catheters to supervise trainees who perform catheter insertion (39,43,46,182,187,188). **Category IA**
- E. Use totally implantable access devices for patients who require long-term, intermittent vascular access. For patients requiring frequent or continuous access, a PICC or tunneled CVC is preferable (256,257). **Category II**
- F. Use a cuffed CVC for dialysis if the period of temporary access is anticipated to be prolonged (e.g., >3 weeks) (144,258). **Category IB**
- G. Use a fistula or graft instead of a CVC for permanent access for dialysis (142). **Category IB**
- H. Do not use hemodialysis catheters for blood drawing or applications other than hemodialysis except during dialysis or under emergency circumstances. **Category II**
- I. Use povidone-iodine antiseptic ointment at the hemodialysis catheter exit site after catheter insertion and at the end of each dialysis session only if this ointment does not interact with the material of the hemodialysis catheter per manufacturer's recommendation (103,114,144). **Category II**
- III. Selection of catheter insertion site
- A. Weigh the risk and benefits of placing a device at a recommended site to reduce infectious complications against the risk for mechanical complications (e.g., pneumothorax, subclavian artery puncture, subclavian vein laceration, subclavian vein stenosis, hemothorax, thrombosis, air embolism, and catheter misplacement) (22,55,59,218). **Category IA**
- B. Use a subclavian site (rather than a jugular or a femoral site) in adult patients to minimize infection risk for nontunneled CVC placement (22,55,59,60). **Category IA**
- C. No recommendation can be made for a preferred site of insertion to minimize infection risk for a nontunneled CVC (61–63). **Unresolved issue**
- D. Place catheters used for hemodialysis and pheresis in a jugular or femoral vein rather than a subclavian vein to avoid venous stenosis if catheter access is needed (259–263). **Category IA**
- IV. Maximal sterile barrier precautions during catheter insertion
- A. Use aseptic technique including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet, for the insertion of CVCs (including PICCS) or guidewire exchange (22,71). **Category IA**
- B. Use a sterile sleeve to protect pulmonary artery catheters during insertion (148). **Category IB**
- V. Replacement of catheter
- A. Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery catheters to prevent catheter-related infections (132,134,135). **Category IB**
- B. Do not remove CVCs or PICCs on the basis of fever alone. Use clinical judgment regarding the appropriateness of removing the catheter if infection is evidenced elsewhere or if a noninfectious cause of fever is suspected (224,264). **Category II**
- C. Guidewire exchange
- Do not use guidewire exchanges routinely for nontunneled catheters to prevent infection (135,265). **Category IB**
 - Use a guidewire exchange to replace a malfunctioning nontunneled catheter if no evidence of infection is present (135,265). **Category IB**
 - Use a new set of sterile gloves before handling the new catheter when guidewire exchanges are performed (22,71). **Category II**
- VI. Catheter and catheter-site care
- A. General measures
- Designate one port exclusively for hyperalimentation if a multilumen catheter is used to administer parenteral nutrition (266). **Category II**
- B. Antibiotic lock solutions
- Do not routinely use antibiotic lock solutions to prevent CRBSI. Use prophylactic antibiotic lock solution only in special circumstances (e.g., in treating a patient with a long-term cuffed or tunneled catheter or port who has a history of multiple CRBSIs despite optimal maximal adherence to aseptic technique) (115,116,267,268). **Category II**
- C. Catheter-site dressing regimens
- Replace the catheter-site dressing when it becomes damp, loosened, or soiled or when inspection of the site is necessary (65,146,211). **Category IA**
 - Replace dressings used on short-term CVC sites every 2 days for gauze dressings and at least every 7 days for transparent dressings, except in those pediatric patients in which the risk for dislodging the catheter outweighs the benefit of changing the dressing (211). **Category IB**
 - Replace dressings used on tunneled or implanted CVC sites no more than once per week, until the insertion site has healed (211). **Category IB**

4. No recommendation can be made regarding the necessity for any dressing on well-healed exit sites of long-term cuffed and tunneled CVCs. **Unresolved issue**
- D. No recommendation can be made for the use of chlorhexidine sponge dressings to reduce the incidence of infection. **Unresolved issue**
- E. Do not use chlorhexidine sponge dressings in neonates aged <7 days or of gestational age <26 weeks (181). **Category II**
- F. No recommendation can be made for the use of sutureless securement devices. **Unresolved issue**
- G. Ensure that catheter-site care is compatible with the catheter material (109,110). **Category IB**
- H. Use a sterile sleeve for all pulmonary artery catheters (148). **Category IB**

Additional Recommendations for Peripheral Arterial Catheters and Pressure Monitoring Devices for Adult and Pediatric Patients

- I. Selection of pressure monitoring system
 - Use disposable, rather than reusable, transducer assemblies when possible (269–273). **Category IB**
- II. Replacement of catheter and pressure monitoring system
 - A. Do not routinely replace peripheral arterial catheters to prevent catheter-related infections (132,147,221,274). **Category II**
 - B. Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system (including the tubing, continuous-flush device, and flush solution) at the time the transducer is replaced (22,270). **Category IB**
- III. Care of pressure monitoring systems
 - A. General measures
 1. Keep all components of the pressure monitoring system (including calibration devices and flush solution) sterile (269,275–277). **Category IA**
 2. Minimize the number of manipulations of and entries into the pressure monitoring system. Use a closed-flush system (i.e., continuous flush), rather than an open system (i.e., one that requires a syringe and stopcock), to maintain the patency of the pressure monitoring catheters (272,278). **Category II**
 3. When the pressure monitoring system is accessed through a diaphragm rather than a stopcock, wipe the diaphragm with an appropriate antiseptic before accessing the system (272). **Category IA**

4. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit (272,279,280). **Category IA**
- B. Sterilization or disinfection of pressure monitoring systems
 1. Use disposable transducers (272,279–282). **Category IB**
 2. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible (272,279–282). **Category IA**

Recommendations for Umbilical Catheters

- I. Replacement of catheters
 - A. Remove and do not replace umbilical artery catheters if any signs of CRBSI, vascular insufficiency, or thrombosis are present (283). **Category II**
 - B. Remove and do not replace umbilical venous catheters if any signs of CRBSI or thrombosis are present (283). **Category II**
 - C. No recommendation can be made for treating through an umbilical venous catheter suspected of being infected. **Unresolved issue**
 - D. Replace umbilical venous catheters only if the catheter malfunctions. **Category II**
- II. Catheter-site care
 - A. Cleanse the umbilical insertion site with an antiseptic before catheter insertion. Avoid tincture of iodine because of the potential effect on the neonatal thyroid. Other iodine-containing products (e.g., povidone-iodine) can be used (75,177,178,284,285). **Category IB**
 - B. Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance (107,213). **Category IA**
 - C. Add low doses of heparin (0.25–1.0 F/ml) to the fluid infused through umbilical arterial catheters (286–288). **Category IB**
 - D. Remove umbilical catheters as soon as possible when no longer needed or when any sign of vascular insufficiency to the lower extremities is observed. Optimally, umbilical artery catheters should not be left in place >5 days (283,289). **Category II**
 - E. Umbilical venous catheters should be removed as soon as possible when no longer needed but can be used up to 14 days if managed aseptically (290,291). **Category II**

References

1. Pearson ML. Guideline for prevention of intravascular device-related infections. Part I. Intravascular device-related infections: an overview. The Hospital Infection Control Practices Advisory Committee. *Am J Infect Control* 1996;24:262–77.
2. Mermel LA. Prevention of intravascular catheter-related infections. *Ann Intern Med* 2000;132:391–402.
3. CDC. National Nosocomial Infections Surveillance (NNIS) System report, data summary from October 1986–April 1998, issued June 1998. *Am J Infect Control* 1998;26:522–33.
4. Digiovine B, Chenoweth C, Watts C, Higgins M. The attributable mortality and costs of primary nosocomial bloodstream infections in the intensive care unit. *Am J Respir Crit Care Med* 1999;160:976–81.
5. Rello J, Ochagavia A, Sabanes E, et al. Evaluation of outcome of intravenous catheter-related infections in critically ill patients. *Am J Respir Crit Care Med* 2000;162:1027–30.
6. Soufir L, Timsit JF, Mahe C, Carlet J, Regnier B, Chevret S. Attributable morbidity and mortality of catheter-related septicemia in critically ill patients: a matched, risk-adjusted, cohort study. *Infect Control Hosp Epidemiol* 1999;20:396–401.
7. Collignon PJ. Intravascular catheter associated sepsis: a common problem. The Australian Study on Intravascular Catheter Associated Sepsis. *Med J Aust* 1994;161:374–8.
8. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. *JAMA* 1994;271:1598–601.
9. Dimick JB, Pelz RK, Consunji R, Swoboda SM, Hendrix CW, Lipsett PA. Increased resource use associated with catheter-related bloodstream infection in the surgical intensive care unit. *Arch Surg* 2001;136:229–34.
10. Mermel LA. Correction: catheter related bloodstream-infections. *Ann Intern Med* 2000;133:395.
11. Kluger DM, Maki DG. The relative risk of intravascular device related bloodstream infections in adults [Abstract]. In: Abstracts of the 39th Interscience Conference on Antimicrobial Agents and Chemotherapy. San Francisco, CA: American Society for Microbiology, 1999:514.
12. CDC. National Nosocomial Infections Surveillance (NNIS) System report, data summary from January 1990–May 1999, issued June 1999. *Am J Infect Control* 1999;27:520–32.
13. Joint Commission on the Accreditation of Healthcare Organizations. Accreditation manual for hospitals. In: Joint Commission on the Accreditation of Healthcare Organizations, ed. Chicago, IL: Joint Commission on the Accreditation of Healthcare Organizations, 1994:121–40.
14. CDC. National Nosocomial Infections Surveillance (NNIS) System report, data summary from January 1992–June 2001, issued August 2001. *Am J Infect Control* 2001;6:404–21.
15. Schaberg DR, Culver DH, Gaynes RP. Major trends in the microbial etiology of nosocomial infection. *Am J Med* 1991;91(suppl):S72–S75.
16. Banerjee SN, Emori TG, Culver DH, et al. Secular trends in nosocomial primary bloodstream infections in the United States, 1980–1989. National Nosocomial Infections Surveillance System. *Am J Med* 1991;91(suppl):S86–S89.
17. Pfaller MA, Jones RN, Messer SA, Edmond MB, Wenzel RP. National surveillance of nosocomial blood stream infection due to *Candida albicans*: frequency of occurrence and antifungal susceptibility in the SCOPE Program. *Diagn Microbiol Infect Dis* 1998;31:327–32.
18. Pfaller MA, Jones RN, Messer SA, Edmond MB, Wenzel RP. National surveillance of nosocomial blood stream infection due to species of *Candida* other than *Candida albicans*: frequency of occurrence and antifungal susceptibility in the SCOPE Program. *Diagn Microbiol Infect Dis* 1998;30:121–9.
19. Nguyen MH, Peacock JE Jr., Morris AJ, et al. The changing face of candidemia: emergence of non-*Candida albicans* species and antifungal resistance. *Am J Med* 1996;100:617–23.
20. Fridkin SK, Gaynes RP. Antimicrobial resistance in intensive care units. *Clin Chest Med* 1999;20:303–16.
21. Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous-catheter-related infection. *N Engl J Med* 1977;296:1305–9.
22. Mermel LA, McCormick RD, Springman SR, Maki DG. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. *Am J Med* 1991;91(suppl):S197–S205.
23. Sitges-Serra A, Linares J, Perez JL, Jaurrieta E, Lorente L. A randomized trial on the effect of tubing changes on hub contamination and catheter sepsis during parenteral nutrition. *Parenter Enteral Nutr* 1985;9:322–5.
24. Linares J, Sitges-Serra A, Garau J, Perez JL, Martin R. Pathogenesis of catheter sepsis: a prospective study with quantitative and semiquantitative cultures of catheter hub and segments. *J Clin Microbiol* 1985;21:357–60.
25. Raad II, Costerton W, Sabharwal U, Sacilowski M, Anaissie E, Bodey GP. Ultrastructural analysis of indwelling vascular catheters: a quantitative relationship between luminal colonization and duration of placement. *J Infect Dis* 1993;168:400–7.
26. Maki DG. Infections associated with intravascular lines. In: Remington JS, ed. *Current Clinical Topics in Infectious Diseases*. New York: McGraw-Hill, 1982:309–63.
27. Sheth NK, Franson TR, Rose HD, Buckmire FL, Cooper JA, Sohnle PG. Colonization of bacteria on polyvinyl chloride and Teflon intravascular catheters in hospitalized patients. *J Clin Microbiol* 1983;18:1061–3.
28. Ashkenazi S, Weiss E, Drucker MM, Bodey GP. Bacterial adherence to intravenous catheters and needles and its influence by cannula type and bacterial surface hydrophobicity. *J Lab Clin Med* 1986;107:136–40.
29. Locci R, Peters G, Pulverer G. Microbial colonization of prosthetic devices. IV. Scanning electron microscopy of intravenous catheters invaded by yeasts. *Zentralbl Bakteriell Mikrobiol Hyg [B]* 1981;173:419–24.
30. Locci R, Peters G, Pulverer G. Microbial colonization of prosthetic devices. I. Microtopographical characteristics of intravenous catheters as detected by scanning electron microscopy. *Zentralbl Bakteriell Mikrobiol Hyg [B]* 1981;173:285–92.
31. Nachnani GH, Lessin LS, Motomiya T, Jensen WN, Bodey GP. Scanning electron microscopy of thrombogenesis on vascular catheter surfaces. *N Engl J Med* 1972;286:139–40.
32. Stillman RM, Soliman F, Garcia L, Sawyer PN. Etiology of catheter-associated sepsis. Correlation with thrombogenicity. *Arch Surg* 1977;112:1497–9.
33. Herrmann M, Lai QJ, Albrecht RM, Mosher DF, Proctor RA. Adhesion of *Staphylococcus aureus* to surface-bound platelets: role of fibrinogen/fibrin and platelet integrins. *J Infect Dis* 1993;167:312–22.
34. Herrmann M, Suchard SJ, Boxer LA, Waldvogel FA, Lew PD. Thrombospondin binds to *Staphylococcus aureus* and promotes staphylococcal adherence to surfaces. *Infect Immun* 1991;59:279–88.

35. Ludwicka A, Uhlenbruck G, Peters G, et al. Investigation on extracellular slime substance produced by *Staphylococcus epidermidis*. *Zentralbl Bakteriell Mikrobiol Hyg* 1984;258:256–67.
36. Gray ED, Peters G, Versteegen M, Regelman WE. Effect of extracellular slime substance from *Staphylococcus epidermidis* on the human cellular immune response. *Lancet* 1984;1:365–7.
37. Farber BF, Kaplan MH, Clogston AG. *Staphylococcus epidermidis* extracted slime inhibits the antimicrobial action of glycopeptide antibiotics. *J Infect Dis* 1990;161:37–40.
38. Branchini ML, Pfaller MA, Rhine-Chalberg J, Frempong T, Isenberg HD. Genotypic variation and slime production among blood and catheter isolates of *Candida parapsilosis*. *J Clin Microbiol* 1994;32:452–6.
39. Sherertz RJ, Ely EW, Westbrook DM, et al. Education of physicians-in-training can decrease the risk for vascular catheter infection. *Ann Intern Med* 2000;132:641–8.
40. Ryan JA Jr., Abel RM, Abbott WM, et al. Catheter complications in total parenteral nutrition: a prospective study of 200 consecutive patients. *N Engl J Med* 1974;290:757–61.
41. Sanders RA, Sheldon GF. Septic complications of total parenteral nutrition: a five year experience. *Am J Surg* 1976;132:214–20.
42. Murphy LM, Lipman TO. Central venous catheter care in parenteral nutrition: a review. *Parenter Enteral Nutr* 1987;11:190–201.
43. Eggimann P, Harbarth S, Constantin MN, Touveneau S, Chevrolet JC, Pittet D. Impact of a prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care. *Lancet* 2000;355:1864–8.
44. Armstrong CW, Mayhall CG, Miller KB, et al. Prospective study of catheter replacement and other risk factors for infection of hyperalimentation catheters. *J Infect Dis* 1986;154:808–16.
45. Nehme AE. Nutritional support of the hospitalized patient: the team concept. *JAMA* 1980;243:1906–8.
46. Soifer NE, Borzak S, Edlin BR, Weinstein RA. Prevention of peripheral venous catheter complications with an intravenous therapy team: a randomized controlled trial. *Arch Intern Med* 1998;158:473–7.
47. Tomford JW, Hershey CO. The IV therapy team: impact on patient care and costs of hospitalization. *NITA* 1985;8:387–9.
48. Fridkin SK, Pear SM, Williamson TH, Galgiani JN, Jarvis WR. The role of understaffing in central venous catheter-associated bloodstream infections. *Infect Control Hosp Epidemiol* 1996;17:150–8.
49. Bansmer G, Keith D, Tesluk H. Complications following use of indwelling catheters of inferior vena cava. *JAMA* 1958;167:1606–11.
50. Crane C. Venous interruption of septic thrombophlebitis. *N Engl J Med* 1960;262:947–51.
51. Indar R. The dangers of indwelling polyethylene cannulae in deep veins. *Lancet* 1959;1:284–6.
52. Maki DG, Mermel LA. Infections due to infusion therapy. In: Bennett JV, Brachman PS, eds. *Hospital Infections*. 4th ed. Philadelphia: Lippincott-Raven, 1998:689–724.
53. Heard SO, Wagle M, Vijayakumar E, et al. Influence of triple-lumen central venous catheters coated with chlorhexidine and silver sulfadiazine on the incidence of catheter-related bacteremia. *Arch Intern Med* 1998;158:81–7.
54. Richet H, Hubert B, Nitemberg G, et al. Prospective multicenter study of vascular-catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. *J Clin Microbiol* 1990;28:2520–5.
55. Goetz AM, Wagener MM, Miller JM, Muder RR. Risk of infection due to central venous catheters: effect of site of placement and catheter type. *Infect Control Hosp Epidemiol* 1998;19:842–5.
56. Joynt GM, Kew J, Gomersall CD, Leung VY, Liu EK. Deep venous thrombosis caused by femoral venous catheters in critically ill adult patients. *Chest* 2000;117:178–83.
57. Mian NZ, Bayly R, Schreck DM, Besserman EB, Richmand D. Incidence of deep venous thrombosis associated with femoral venous catheterization. *Acad Emerg Med* 1997;4:1118–21.
58. Durbec O, Viviani X, Potie F, Vialet R, Albanese J, Martin C. A prospective evaluation of the use of femoral venous catheters in critically ill adults. *Crit Care Med* 1997;25:1986–9.
59. Trotter SJ, Veremakis C, O'Brien J, Auer AI. Femoral deep vein thrombosis associated with central venous catheterization: results from a prospective, randomized trial. *Crit Care Med* 1995;23:52–9.
60. Merrer J, De Jonghe B, Golliot F, et al. Complications of femoral and subclavian venous catheterization in critically ill patients: a randomized controlled trial. *JAMA* 2001;286:700–7.
61. Venkataraman ST, Thompson AE, Orr RA. Femoral vascular catheterization in critically ill infants and children. *Clin Pediatr* 1997;36:311–9.
62. Stenzel JP, Green TP, Fuhrman BP, Carlson PE, Marchessault RP. Percutaneous femoral venous catheterizations: a prospective study of complications. *J Pediatr* 1989;114:411–5.
63. Goldstein AM, Weber JM, Sheridan RL. Femoral venous access is safe in burned children: an analysis of 224 catheters. *J Pediatr* 1997;130:442–6.
64. Randolph AG, Cook DJ, Gonzales CA, Pribble CG. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Crit Care Med* 1996;24:2053–8.
65. Maki DG, Ringer M. Evaluation of dressing regimens for prevention of infection with peripheral intravenous catheters: gauze, a transparent polyurethane dressing, and an iodophor-transparent dressing. *JAMA* 1987;258:2396–403.
66. Maki DG, Ringer M. Risk factors for infusion-related phlebitis with small peripheral venous catheters: a randomized controlled trial. *Ann Intern Med* 1991;114:845–54.
67. Band JD, Maki DG. Steel needles used for intravenous therapy: morbidity in patients with hematologic malignancy. *Arch Intern Med* 1980;140:31–4.
68. Tully JL, Friedland GH, Baldini LM, Goldmann DA. Complications of intravenous therapy with steel needles and Teflon[®] catheters: a comparative study. *Am J Med* 1981;70:702–6.
69. Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *Lancet* 2000;356:1307–9.
70. Larson EL, Rackoff WR, Weiman M, et al. APIC guideline for handwashing and hand antisepsis in health care settings. *Am J Infect Control* 1995;23:251–69.
71. Raad II, Hohn DC, Gilbreath BJ, et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infect Control Hosp Epidemiol* 1994;15:231–8.
72. Clemence MA, Walker D, Farr BM. Central venous catheter practices: results of a survey. *Am J Infect Control* 1995;23:5–12.
73. Maki DG, Ringer M, Alvarado CJ. Prospective randomized trial of povidone-iodine, alcohol, and chlorhexidine for prevention of infection associated with central venous and arterial catheters. *Lancet* 1991;338:339–43.
74. Humar A, Ostromecki A, Drenfeld J, et al. Prospective randomized trial of 10% povidone-iodine versus 0.5% tincture of chlorhexidine as cutaneous antisepsis for prevention of central venous catheter infection. *Clin Infect Dis* 2000;31:1001–7.

75. Garland JS, Buck RK, Maloney P, et al. Comparison of 10% povidone-iodine and 0.5% chlorhexidine gluconate for the prevention of peripheral intravenous catheter colonization in neonates: a prospective trial. *Pediatr Infect Dis J* 1995;14:510–6.
76. Hoffmann KK, Weber DJ, Samsa GP, Rutala WA. Transparent polyurethane film as an intravenous catheter dressing: a meta-analysis of the infection risks. *JAMA* 1992;267:2072–6.
77. Maki DG, Mermel LA, Klugar D, et al. The efficacy of a chlorhexidine impregnated sponge (Biopatch) for the prevention of intravascular catheter-related infection— a prospective randomized controlled multicenter study [Abstract]. Presented at the Interscience Conference on Antimicrobial Agents and Chemotherapy. Toronto, Ontario, Canada: American Society for Microbiology, 2000.
78. Yamamoto AJ, Solomon JA, Soulen MC, et al. Sutureless securement device reduces complications of peripherally inserted central venous catheters. *J Vasc Interv Radiol* 2001 (in press).
79. Rusho WJ, Bair JN. Effect of filtration on complications of postoperative intravenous therapy. *Am J Hosp Pharm* 1979;36:1355–6.
80. Maddox RR, John JF Jr, Brown LL, Smith CE. Effect of inline filtration on postinfusion phlebitis. *Clin Pharm* 1983;2:58–61.
81. Turco SJ, Davis NM. Particulate matter in intravenous infusion fluids—phase 3. *Am J Hosp Pharm* 1973;30:611–3.
82. Baumgartner TG, Schmidt GL, Thakker KM, et al. Bacterial endotoxin retention by inline intravenous filters. *Am J Hosp Pharm* 1986;43:681–4.
83. Butler DL, Munson JM, DeLuca PP. Effect of inline filtration on the potency of low-dose drugs. *Am J Hosp Pharm* 1980;37:935–41.
84. Raad II, Darouiche R, Dupuis J, et al. Central venous catheters coated with minocycline and rifampin for the prevention of catheter-related colonization and bloodstream infections: a randomized, double-blind trial. The Texas Medical Center Catheter Study Group. *Ann Intern Med* 1997;127:267–74.
85. Veenstra DL, Saint S, Saha S, Lumley T, Sullivan SD. Efficacy of antiseptic-impregnated central venous catheters in preventing catheter-related bloodstream infection: a meta-analysis. *JAMA* 1999;281:261–7.
86. Maki DG, Stolz SM, Wheeler S, Mermel LA. Prevention of central venous catheter-related bloodstream infection by use of an antiseptic-impregnated catheter: a randomized, controlled trial. *Ann Intern Med* 1997;127:257–66.
87. Raad II, Darouiche R, Hachem R, Mansouri M, Bodey GP. The broad-spectrum activity and efficacy of catheters coated with minocycline and rifampin. *J Infect Dis* 1996;173:418–24.
88. Bassetti S, Hu J, D'Agostino RB Jr, Sherertz RJ. Prolonged antimicrobial activity of a catheter containing chlorhexidine-silver sulfadiazine extends protection against catheter infections in vivo. *Antimicrob Agents Chemother* 2001;45:1535–8.
89. Oda T, Hamasaki J, Kanda N, Mikami K. Anaphylactic shock induced by an antiseptic-coated central venous catheter. *Anesthesiology* 1997;87:1242–4.
90. Veenstra DL, Saint S, Sullivan SD. Cost-effectiveness of antiseptic-impregnated central venous catheters for the prevention of catheter-related bloodstream infection. *JAMA* 1999;282:554–60.
91. Darouiche RO, Raad II, Heard SO, et al. A comparison of two antimicrobial-impregnated central venous catheters. Catheter Study Group. *N Engl J Med* 1999;340:1–8.
92. Institute of Medicine. To err is human: building a safer health system. Washington, DC: National Academy Press, 2000.
93. Maki DG, Cobb L, Garman JK, Shapiro JM, Ringer M, Helgeson RB. An attachable silver-impregnated cuff for prevention of infection with central venous catheters: a prospective randomized multicenter trial. *Am J Med* 1988;85:307–14.
94. Dahlberg PJ, Agger WA, Singer JR, et al. Subclavian hemodialysis catheter infections: a prospective, randomized trial of an attachable silver-impregnated cuff for prevention of catheter-related infections. *Infect Control Hosp Epidemiol* 1995;16:506–11.
95. Groeger JS, Lucas AB, Coit D, et al. A prospective, randomized evaluation of the effect of silver impregnated subcutaneous cuffs for preventing tunneled chronic venous access catheter infections in cancer patients. *Ann Surg* 1993;218:206–10.
96. Bonawitz SC, Hammell EJ, Kirkpatrick JR. Prevention of central venous catheter sepsis: a prospective randomized trial. *Am Surg* 1991;57:618–23.
97. McKee R, Dunsmuir R, Whitby M, Garden OJ. Does antibiotic prophylaxis at the time of catheter insertion reduce the incidence of catheter-related sepsis in intravenous nutrition? *J Hosp Infect* 1985;6:419–25.
98. Ranson MR, Oppenheim BA, Jackson A, Kamthan AG, Scarffe JH. Double-blind placebo controlled study of vancomycin prophylaxis for central venous catheter insertion in cancer patients. *J Hosp Infect* 1990;15:95–102.
99. Ljungman P, Hagglund H, Bjorkstrand B, Lonnqvist B, Ringden O. Perioperative teicoplanin for prevention of gram-positive infections in neutropenic patients with indwelling central venous catheters: a randomized, controlled study. *Support Care Cancer* 1997;5:485–8.
100. Kacica MA, Horgan MJ, Ochoa L, Sandler R, Lepow ML, Venezia RA. Prevention of gram-positive sepsis in neonates weighing less than 1500 g. *J Pediatr* 1994;125:253–8.
101. Spafford PS, Sinkin RA, Cox C, Reubens L, Powell KR. Prevention of central venous catheter-related coagulase-negative staphylococcal sepsis in neonates. *J Pediatr* 1994;125:259–63.
102. CDC. Recommendations for preventing the spread of vancomycin resistance. Recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC). *MMWR* 1995;44(No. RR-12).
103. Levin A, Mason AJ, Jindal KK, Fong IW, Goldstein MB. Prevention of hemodialysis subclavian vein catheter infections by topical povidone-iodine. *Kidney Int* 1991;40:934–8.
104. Casewell MW. The nose: an underestimated source of *Staphylococcus aureus* causing wound infection. *J Hosp Infect* 1998;40(suppl):S3–S11.
105. Hill RL, Fisher AP, Ware RJ, Wilson S, Casewell MW. Mupirocin for the reduction of colonization of internal jugular cannulae—a randomized controlled trial. *J Hosp Infect* 1990;15:311–21.
106. Sesso R, Barbosa D, Leme IL, et al. *Staphylococcus aureus* prophylaxis in hemodialysis patients using central venous catheter: effect of mupirocin ointment. *J Am Soc Nephrol* 1998;9:1085–92.
107. Zakrzewska-Bode A, Muyltjens HL, Liem KD, Hoogkamp-Korstanje JA. Mupirocin resistance in coagulase-negative staphylococci, after topical prophylaxis for the reduction of colonization of central venous catheters. *J Hosp Infect* 1995;31:189–93.
108. Miller MA, Dascal A, Portnoy J, Mendelson J. Development of mupirocin resistance among methicillin-resistant *Staphylococcus aureus* after widespread use of nasal mupirocin ointment. *Infect Control Hosp Epidemiol* 1996;17:811–3.
109. Rao SP, Oreopoulos DG. Unusual complications of a polyurethane PD catheter. *Perit Dial Int* 1997;17:410–2.
110. Riu S, Ruiz CG, Martinez-Vea A, Peralta C, Oliver JA. Spontaneous rupture of polyurethane peritoneal catheter: a possible deleterious effect of mupirocin ointment. *Nephrol Dial Transplant* 1998;13:1870–1.

111. von Eiff C, Becker K, Machka K, Stammer H, Peters G. Nasal carriage as a source of *Staphylococcus aureus* bacteremia. *N Engl J Med* 2001;344:11–6.
112. Zinner SH, Denny-Brown BC, Braun P, Burke JP, Toala P, Kass EH. Risk of infection with intravenous indwelling catheters: effect of application of antibiotic ointment. *J Infect Dis* 1969;120:616–9.
113. Norden CW. Application of antibiotic ointment to the site of venous catheterization—a controlled trial. *J Infect Dis* 1969;120:611–5.
114. Maki DG, Band JD. A comparative study of polyantibiotic and iodophor ointments in prevention of vascular catheter-related infection. *Am J Med* 1981;70:739–44.
115. Henrickson KJ, Axtell RA, Hoover SM, et al. Prevention of central venous catheter-related infections and thrombotic events in immunocompromised children by the use of vancomycin/ciprofloxacin/heparin flush solution: a randomized, multicenter, double-blind trial. *J Clin Oncol* 2000;18:1269–78.
116. Carratala J, Niubo J, Fernandez-Sevilla A, et al. Randomized, double-blind trial of an antibiotic-lock technique for prevention of gram-positive central venous catheter-related infection in neutropenic patients with cancer. *Antimicrob Agents Chemother* 1999;43:2200–4.
117. Schwartz C, Henrickson KJ, Roghmann K, Powell K. Prevention of bacteremia attributed to luminal colonization of tunneled central venous catheters with vancomycin-susceptible organisms. *J Clin Oncol* 1990;8:1591–7.
118. Rackoff WR, Weiman M, Jakobowski D, et al. A randomized, controlled trial of the efficacy of a heparin and vancomycin solution in preventing central venous catheter infections in children. *J Pediatr* 1995;127:147–51.
119. Raad II, Buzaid A, Rhyne J, et al. Minocycline and ethylene-diaminetetraacetate for the prevention of recurrent vascular catheter infections. *Clin Infect Dis* 1997;25:149–51.
120. Raad II, Luna M, Khalil SA, Costerton JW, Lam C, Bodey GP. The relationship between the thrombotic and infectious complications of central venous catheters. *JAMA* 1994;271:1014–6.
121. Timsit JF, Farkas JC, Boyer JM, et al. Central vein catheter-related thrombosis in intensive care patients: incidence, risk factors, and relationship with catheter-related sepsis. *Chest* 1998;114:207–13.
122. Randolph AG, Cook DJ, Gonzales CA, Andrew M. Benefit of heparin in central venous and pulmonary artery catheters: a meta-analysis of randomized controlled trials. *Chest* 1998;113:165–71.
123. Mermel LA, Stolz SM, Maki DG. Surface antimicrobial activity of heparin-bonded and antiseptic-impregnated vascular catheters. *J Infect Dis* 1993;167:920–4.
124. Pierce CM, Wade A, Mok Q. Heparin-bonded central venous lines reduce thrombotic and infective complications in critically ill children. *Intensive Care Med* 2000;26:967–72.
125. Bern MM, Lokich JJ, Wallach SR, et al. Very low doses of warfarin can prevent thrombosis in central venous catheters: a randomized prospective trial. *Ann Intern Med* 1990;112:423–8.
126. Boraks P, Seale J, Price J, et al. Prevention of central venous catheter associated thrombosis using minidose warfarin in patients with haematological malignancies. *Br J Haematol* 1998;101:483–6.
127. Collin J, Collin C. Infusion thrombophlebitis. *Lancet* 1975;2:458.
128. Lai KK. Safety of prolonging peripheral cannula and i.v. tubing use from 72 hours to 96 hours. *Am J Infect Control* 1998;26:66–70.
129. Fontaine PJ. Performance of a new softening expanding midline catheter in home intravenous therapy patients. *J Intraven Nurs* 1991;14:91–9.
130. Harwood IR, Greene LM, Kozakowski-Koch JA, Rasor JS. New peripherally inserted midline catheter: a better alternative for intravenous antibiotic therapy in patients with cystic fibrosis. *Pediatr Pulmonol* 1992;12:233–9.
131. Mermel LA, Parenteau S, Tow SM. The risk of midline catheterization in hospitalized patients. A prospective study. *Ann Intern Med* 1995;123:841–4.
132. Eyer S, Brummitt C, Crossley K, Siegel R, Cerra F. Catheter-related sepsis: prospective, randomized study of three methods of long-term catheter maintenance. *Crit Care Med* 1990;18:1073–9.
133. Uldall PR, Merchant N, Woods F, Yarworski U, Vas S. Changing subclavian haemodialysis cannulas to reduce infection. *Lancet* 1981;1:1373.
134. Cook D, Randolph A, Kernerman P, et al. Central venous catheter replacement strategies: a systematic review of the literature. *Crit Care Med* 1997;25:1417–24.
135. Cobb DK, High KP, Sawyer RG, et al. A controlled trial of scheduled replacement of central venous and pulmonary-artery catheters. *N Engl J Med* 1992;327:1062–8.
136. Robinson D, Suhocki P, Schwab SJ. Treatment of infected tunneled venous access hemodialysis catheters with guidewire exchange. *Kidney Int* 1998;53:1792–4.
137. Beathard GA. Management of bacteremia associated with tunneled-cuffed hemodialysis catheters. *J Am Soc Nephrol* 1999;10:1045–9.
138. Saad TF. Bacteremia associated with tunneled, cuffed hemodialysis catheters. *Am J Kidney Dis* 1999;34:1114–24.
139. Duszak R Jr., Haskal ZJ, Thomas-Hawkins C, et al. Replacement of failing tunneled hemodialysis catheters through pre-existing subcutaneous tunnels: a comparison of catheter function and infection rates for de novo placements and over-the-wire exchanges. *J Vasc Interv Radiol* 1998;9:321–7.
140. Jaar BG, Hermann JA, Furth SL, Briggs W, Powe NR. Septicemia in diabetic hemodialysis patients: comparison of incidence, risk factors, and mortality with nondiabetic hemodialysis patients. *Am J Kidney Dis* 2000;35:282–92.
141. Powe NR, Jaar B, Furth SL, Hermann J, Briggs W. Septicemia in dialysis patients: incidence, risk factors, and prognosis. *Kidney Int* 1999;55:1081–90.
142. Hoen B, Paul-Dauphin A, Hestin D, Kessler M. EPIBACDIAL: a multicenter prospective study of risk factors for bacteremia in chronic hemodialysis patients. *J Am Soc Nephrol* 1998;9:869–76.
143. Tokars JI, Miller ER, Alter MJ, et al. National surveillance of dialysis-associated diseases in the United States, 1997. *Semin Dial* 2000;13:75–85.
144. Foundation NK. III. NKF-K/DOQI Clinical practice guidelines for vascular access: update 2000. *Am J Kidney Dis* 2001;37(suppl):S137–S81.
145. Mermel LA. Intravascular catheters impregnated with benzalkonium chloride. *J Antimicrob Chemother* 1993;32:905–6.
146. Maki DG, Stolz SS, Wheeler S, Mermel LA. A prospective, randomized trial of gauze and two polyurethane dressings for site care of pulmonary artery catheters: implications for catheter management. *Crit Care Med* 1994;22:1729–37.
147. Raad II, Umphrey J, Khan A, Truett LJ, Bodey GP. The duration of placement as a predictor of peripheral and pulmonary arterial catheter infections. *J Hosp Infect* 1993;23:17–26.
148. Cohen Y, Fosse JP, Karoubi P, et al. The “hands-off” catheter and the prevention of systemic infections associated with pulmonary artery catheter: a prospective study. *Am J Respir Crit Care Med* 1998;157:284–7.

149. Josephson A, Gombert ME, Sierra MF, Karanfil LV, Tansino GF. The relationship between intravenous fluid contamination and the frequency of tubing replacement. *Infect Control* 1985;6:367-70.
150. Maki DG, Botticelli JT, LeRoy ML, Thielke TS. Prospective study of replacing administration sets for intravenous therapy at 48- vs 72-hour intervals: 72 hours is safe and cost-effective. *JAMA* 1987;258:1777-81.
151. Snyderman DR, Donnelly-Reidy M, Perry LK, Martin WJ. Intravenous tubing containing burettes can be safely changed at 72 hour intervals. *Infect Control* 1987;8:113-6.
152. Hanna HA, Raad II. Blood products: a significant risk factor for long-term catheter-related bloodstream infections in cancer patients. *Infect Control Hosp Epidemiol* 2001;22:165-6.
153. Raad II, Hanna HA, Awad A, et al. Optimal frequency of changing intravenous administration sets: is it safe to prolong use beyond 72 hours? *Infect Control Hosp Epidemiol* 2001;22:136-9.
154. Saiman L, Ludington E, Dawson JD, et al. Risk factors for *Candida* species colonization of neonatal intensive care unit patients. *Pediatr Infect Dis J* 2001;20:1119-24.
155. Avila-Figueroa C, Goldmann DA, Richardson DK, Gray JE, Ferrari A, Freeman J. Intravenous lipid emulsions are the major determinant of coagulase-negative staphylococcal bacteremia in very low birth weight newborns. *Pediatr Infect Dis J* 1998;17:10-7.
156. Crocker KS, Noga R, Filibeck DJ, Krey SH, Markovic M, Steffee WP. Microbial growth comparisons of five commercial parenteral lipid emulsions. *J Parenter Enteral Nutr* 1984;8:391-5.
157. Jarvis WR, Highsmith AK. Bacterial growth and endotoxin production in lipid emulsion. *J Clin Microbiol* 1984;19:17-20.
158. Melly MA, Meng HC, Schaffner W. Microbiol growth in lipid emulsions used in parenteral nutrition. *Arch Surg* 1975;110:1479-81.
159. Inoue Y, Nezu R, Matsuda H, et al. Prevention of catheter-related sepsis during parenteral nutrition: effect of a new connection device. *J Parenter Enteral Nutr* 1992;16:581-5.
160. Arduino MJ, Bland LA, Danzig LE, McAllister SK, Aguero SM. Microbiologic evaluation of needleless and needle-access devices. *Am J Infect Control* 1997;25:377-80.
161. Brown JD, Moss HA, Elliott TS. The potential for catheter microbial contamination from a needleless connector. *J Hosp Infect* 1997;36:181-9.
162. Cookson ST, Ihrig M, O'Mara EM, et al. Increased bloodstream infection rates in surgical patients associated with variation from recommended use and care following implementation of a needleless device. *Infect Control Hosp Epidemiol* 1998;19:23-7.
163. Do AN, Ray BJ, Banerjee SN, et al. Bloodstream infection associated with needleless device use and the importance of infection-control practices in the home health care setting. *J Infect Dis* 1999;179:442-8.
164. Luebke MA, Arduino MJ, Duda DL, et al. Comparison of the microbial barrier properties of a needleless and a conventional needle-based intravenous access system. *Am J Infect Control* 1998;26:437-41.
165. McDonald LC, Banerjee SN, Jarvis WR. Line-associated bloodstream infections in pediatric intensive-care-unit patients associated with a needleless device and intermittent intravenous therapy. *Infect Control Hosp Epidemiol* 1998;19:772-7.
166. Mendelson MH, Short LJ, Schechter CB, et al. Study of a needleless intermittent intravenous-access system for peripheral infusions: analysis of staff, patient, and institutional outcomes. *Infect Control Hosp Epidemiol* 1998;19:401-6.
167. Seymour VM, Dhallu TS, Moss HA, Tebbs SE, Elliot TS. A prospective clinical study to investigate the microbial contamination of a needleless connector. *J Hosp Infect* 2000;45:165-8.
168. Longfield RN, Smith LP, Longfield JN, Coberly J, Cruess D. Multiple-dose vials: persistence of bacterial contaminants and infection control implications. *Infect Control* 1985;6:194-9.
169. Henry B, Plante-Jenkins C, Ostrowska K. An outbreak of *Serratia marcescens* associated with the anesthetic agent propofol. *Am J Infect Control* 2001;29:312-5.
170. Grohskopf LA, Roth VR, Feikin DR, et al. *Serratia liquefaciens* bloodstream infections from contamination of epoetin alfa at a hemodialysis center. *N Engl J Med* 2001;344:1491-7.
171. CDC. National Nosocomial Infections Surveillance (NNIS) System report, data summary from April 1995-April 2000, issued June 2000. *Am J Infect Control* 2000;28:429-35.
172. Richards MJ, Edwards JR, Culver DH, Gaynes RP. Nosocomial infections in pediatric intensive care units in the United States: National Nosocomial Infections Surveillance System. *Pediatrics* 1999;103:103-9.
173. Richards MJ, Edwards JR, Culver DH, Gaynes RP. Nosocomial infections in medical intensive care units in the United States: National Nosocomial Infections Surveillance System. *Crit Care Med* 1999;27:887-92.
174. Garland JS, Dunne WM Jr., Havens P, et al. Peripheral intravenous catheter complications in critically ill children: a prospective study. *Pediatrics* 1992;89:1145-50.
175. Garland JS, Nelson DB, Cheah TE, Hennes HH, Johnson TM. Infectious complications during peripheral intravenous therapy with Teflon catheters: a prospective study. *Pediatr Infect Dis J* 1987;6:918-21.
176. Furfaro S, Gauthier M, Lacroix J, Nadeau D, Lafleur L, Mathews S. Arterial catheter-related infections in children: a 1-year cohort analysis. *Am J Dis Child* 1991;145:1037-43.
177. Krauss AN, Albert RE, Kannan MM. Contamination of umbilical catheters in the newborn infant. *J Pediatr* 1970;77:965-9.
178. Landers S, Moise AA, Fraley JK, Smith EO, Baker CJ. Factors associated with umbilical catheter-related sepsis in neonates. *Am J Dis Child* 1991;145:675-80.
179. Balagtas RC, Bell CE, Edwards LD, Levin S. Risk of local and systemic infections associated with umbilical vein catheterization: a prospective study in 86 newborn patients. *Pediatrics* 1971;48:359-67.
180. Stenzel JP, Green TP, Fuhrman BP, Carlson PE, Marchessault RP. Percutaneous central venous catheterization in a pediatric intensive care unit: a survival analysis of complications. *Crit Care Med* 1989;17:984-8.
181. Garland JS, Alex CP, Mueller CD, et al. A randomized trial comparing povidone-iodine to a chlorhexidine gluconate-impregnated dressing for prevention of central venous catheter infections in neonates. *Pediatrics* 2001;107:1431-6.
182. Davis D, O'Brien MA, Freemantle N, Wolf FM, Mazmanian P, Taylor-Vaisey A. Impact of formal continuing medical education: do conferences, workshops, rounds, and other traditional continuing education activities change physician behavior or health care outcomes? *JAMA* 1999;282:867-74.
183. Conly JM, Hill S, Ross J, Lertzman J, Louie TJ. Handwashing practices in an intensive care unit: the effects of an educational program and its relationship to infection rates. *Am J Infect Control* 1989;17:330-9.
184. East SA. Planning, implementation, and evaluation of a successful hospital-based peripherally inserted central catheter program. *J Intraven Nurs* 1994;17:189-92.
185. Kyle KS, Myers JS. Peripherally inserted central catheters. Development of a hospital-based program. *J Intraven Nurs* 1990;13:287-90.
186. BeVier PA, Rice CE. Initiating a pediatric peripherally inserted central catheter and midline catheter program. *J Intraven Nurs* 1994;17:201-5.

187. Tomford JW, Hershey CO, McLaren CE, Porter DK, Cohen DI. Intravenous therapy team and peripheral venous catheter-associated complications: a prospective controlled study. *Arch Intern Med* 1984;144:1191-4.
188. Wenzel RP, Wentzel RP. The development of academic programs for quality assessment. *Arch Intern Med* 1991;151:653-4.
189. Robert J, Fridkin SK, Blumberg HM, et al. The influence of the composition of the nursing staff on primary bloodstream infection rates in a surgical intensive care unit. *Infect Control Hosp Epidemiol* 2000;21:12-7.
190. Vicca AF. Nursing staff workload as a determinant of methicillin-resistant *Staphylococcus aureus* spread in an adult intensive therapy unit. *J Hosp Infect* 1999;43:109-13.
191. White MC, Ragland KE. Surveillance of intravenous catheter-related infections among home care clients. *Am J Infect Control* 1994;22:231-5.
192. Lorenzen AN, Itkin DJ. Surveillance of infection in home care. *Am J Infect Control* 1992;20:326-9.
193. White MC. Infections and infection risks in home care settings. *Infect Control Hosp Epidemiol* 1992;13:535-9.
194. Raad II, Baba M, Bodey GP. Diagnosis of catheter-related infections: the role of surveillance and targeted quantitative skin cultures. *Clin Infect Dis* 1995;20:593-7.
195. Widmer AF, Nettleman M, Flint K, Wenzel RP. The clinical impact of culturing central venous catheters: a prospective study. *Arch Intern Med* 1992;152:1299-302.
196. Boyce JM, Farr BM, Jarvis WR, et al. Guideline for hand hygiene in the healthcare setting. *Am J Infect Control* 2002 (in press).
197. Bischoff WE, Reynolds TM, Sessler CN, Edmond MB, Wenzel RP. Handwashing compliance by health care workers: the impact of introducing an accessible, alcohol-based hand antiseptic. *Arch Intern Med* 2000;160:1017-21.
198. Pittet D, Dharan S, Touveneau S, Sauvan V, Perneger TV. Bacterial contamination of the hands of hospital staff during routine patient care. *Arch Intern Med* 1999;159:821-6.
199. Simmons B, Bryant J, Neiman K, Spencer L, Arheart K. The role of handwashing in prevention of endemic intensive care unit infections. *Infect Control Hosp Epidemiol* 1990;11:589-94.
200. Boyce JM, Kelliher S, Vallande N. Skin irritation and dryness associated with two hand-hygiene regimens: soap-and-water hand washing versus hand antiseptics with an alcoholic hand gel. *Infect Control Hosp Epidemiol* 2000;21:442-8.
201. Capdevila JA. Catheter-related infection: an update on diagnosis, treatment, and prevention. *Int J Infect Dis* 1998;2:230-6.
202. Abi-Said D, Raad II, Umphrey J, Gonzalez V, Richardson D, Marts K, Hohn D. Infusion therapy team and dressing changes of central venous catheters. *Infect Control Hosp Epidemiol* 1999;20:101-5.
203. CDC. Update: universal precautions for prevention of transmission of human immunodeficiency virus, hepatitis B virus, and other bloodborne pathogens in health-care settings. *MMWR* 1988;37:377-82, 388.
204. Povoski SP. A prospective analysis of the cephalic vein cutdown approach for chronic indwelling central venous access in 100 consecutive cancer patients. *Ann Surg Oncol* 2000;7:496-502.
205. Arrighi DA, Farnell MB, Mucha P Jr, Istrup DM, Anderson DL. Prospective, randomized trial of rapid venous access for patients in hypovolemic shock. *Ann Emerg Med* 1989;18:927-30.
206. Ahmed Z, Mohyuddin Z. Complications associated with different insertion techniques for Hickman catheters. *Postgrad Med J* 1998;74:104-7.
207. Little JR, Murray PR, Traynor PS, Spitznagel E. A randomized trial of povidone-iodine compared with iodine tincture for venipuncture site disinfection: effects on rates of blood culture contamination. *Am J Med* 1999;107:119-25.
208. Mimos O, Pieroni L, Lawrence C, et al. Prospective, randomized trial of two antiseptic solutions for prevention of central venous or arterial catheter colonization and infection in intensive care unit patients. *Crit Care Med* 1996;24:1818-23.
209. Maki DG, McCormack KN. Defatting catheter insertion sites in total parenteral nutrition is of no value as an infection control measure. Controlled clinical trial. *Am J Med* 1987;83:833-40.
210. Bijma R, Girbes AR, Kleijer DJ, Zwaveling JH. Preventing central venous catheter-related infection in a surgical intensive-care unit. *Infect Control Hosp Epidemiol* 1999;20:618-20.
211. Rasero L, Degl'Innocenti M, Mocali M, et al. Comparison of two different time interval protocols for central venous catheter dressing in bone marrow transplant patients: results of a randomized, multicenter study. *Haematologica* 2000;85:275-9.
212. Madeo M, Martin CR, Turner C, Kirkby V, Thompson DR. A randomized trial comparing Arglae (a transparent dressing containing silver ions) to Tegaderm (a transparent polyurethane dressing) for dressing peripheral arterial catheters and central vascular catheters. *Intensive Crit Care Nurs* 1998;14:187-91.
213. Flowers RH, Schwenger KJ, Kopel RF, Fisch MJ, Tucker SI, Farr BM. Efficacy of an attachable subcutaneous cuff for the prevention of intravascular catheter-related infection: a randomized, controlled trial. *JAMA* 1989;261:878-83.
214. Robbins J, Cromwell P, Korones DN. Swimming and central venous catheter-related infections in the child with cancer. *J Pediatr Oncol Nurs* 1999;16:51-6.
215. Howell PB, Walters PE, Donowitz GR, Farr BM. Risk factors for infection of adult patients with cancer who have tunneled central venous catheters. *Cancer* 1995;75:1367-75.
216. Goetz AM, Miller J, Wagener MM, Muder RR. Complications related to intravenous midline catheter usage: a 2-year study. *J Intraven Nurs* 1998;21:76-80.
217. Martin C, Viviani X, Saux P, Gouin F. Upper-extremity deep vein thrombosis after central venous catheterization via the axillary vein. *Crit Care Med* 1999;27:2626-9.
218. Robinson JF, Robinson WA, Cohn A, Garg K, Armstrong JD. Perforation of the great vessels during central venous line placement. *Arch Intern Med* 1995;155:1225-8.
219. Lederle FA, Parenti CM, Berskow LC, Ellingson KJ. The idle intravenous catheter. *Ann Intern Med* 1992;116:737-8.
220. Parenti CM, Lederle FA, Impola CL, Peterson LR. Reduction of unnecessary intravenous catheter use: internal medicine house staff participate in a successful quality improvement project. *Arch Intern Med* 1994;154:1829-32.
221. Thomas F, Burke JP, Parker J, et al. The risk of infection related to radial vs femoral sites for arterial catheterization. *Crit Care Med* 1983;11:807-12.
222. Nelson DB, Garland JS. The natural history of Teflon catheter-associated phlebitis in children. *Am J Dis Child* 1987;141:1090-2.
223. Shimandle RB, Johnson D, Baker M, Stotland N, Karrison T, Arnow PM. Safety of peripheral intravenous catheters in children. *Infect Control Hosp Epidemiol* 1999;20:736-40.

224. O'Grady NP, Barie PS, Bartlett J, et al. Practice parameters for evaluating new fever in critically ill adult patients. Task Force of the American College of Critical Care Medicine of the Society of Critical Care Medicine in collaboration with the Infectious Disease Society of America. *Crit Care Med* 1998;26:392-408.
225. Mermel LA, Farr BM, Sherertz RJ, et al. Guidelines for the management of intravascular catheter-related infections. *Clin Infect Dis* 2001;32:1249-72.
226. Mershon J, Nogami W, Williams JM, Yoder C, Eitzen HE, Lemons JA. Bacterial/fungal growth in a combined parenteral nutrition solution. *J Parenter Enteral Nutr* 1986;10:498-502.
227. Gilbert M, Gallagher SC, Eads M, Elmore MF. Microbial growth patterns in a total parenteral nutrition formulation containing lipid emulsion. *J Parenter Enteral Nutr* 1986;10:494-7.
228. Maki DG, Martin WT. Nationwide epidemic of septicemia caused by contaminated infusion products. IV. Growth of microbial pathogens in fluids for intravenous infusions. *J Infect Dis* 1975;131:267-72.
229. Didier ME, Fischer S, Maki DG. Total nutrient admixtures appear safer than lipid emulsion alone as regards microbial contamination: growth properties of microbial pathogens at room temperature. *J Parenter Enteral Nutr* 1998;22:291-6.
230. Bennett SN, McNeil MM, Bland LA, et al. Postoperative infections traced to contamination of an intravenous anesthetic, propofol. *N Engl J Med* 1995;333:147-54.
231. Roth VR, Arduino MJ, Nobiletto J, et al. Transfusion-related sepsis due to *Serratia liquefaciens* in the United States. *Transfusion* 2000;40:931-5.
232. Blajchman MA. Reducing the risk of bacterial contamination of cellular blood components. *Dev Biol Stand* 2000;102:183-93.
233. Barrett BB, Andersen JW, Anderson KC. Strategies for the avoidance of bacterial contamination of blood components. *Transfusion* 1993;33:228-33.
234. Wagner SJ, Friedman LI, Dodd RY. Transfusion-associated bacterial sepsis. *Clin Microbiol Rev* 1994;7:290-302.
235. Plott RT, Wagner RF Jr., Tying SK. Iatrogenic contamination of multidose vials in simulated use. A reassessment of current patient injection technique. *Arch Dermatol* 1990;126:1441-4.
236. Salzman MB, Isenberg HD, Rubin LG. Use of disinfectants to reduce microbial contamination of hubs of vascular catheters. *J Clin Microbiol* 1993;31:475-9.
237. ASPH Council on Professional Affairs. ASHP guidelines on quality assurance for pharmacy-prepared sterile products. *Am J Health Syst Pharm* 2000;57:1150-69.
238. Herruzo-Cabrera R, Garcia-Caballero J, Vera-Cortes ML, Vazquez-Encinar A, Garcia-Caballero F, Rey-Calero J, Garcia de Lorenzo A. Growth of microorganisms in parenteral nutrient solutions. *Am J Hosp Pharm* 1984;41:1178-80.
239. Green KA, Shouldachi B, Schoer K, Moro D, Blend R, McGeer A. Gadolinium-based MR contrast media: potential for growth of microbial contaminants when single vials are used for multiple patients. *Am J Roentgenol* 1995;165:669-71.
240. Arrington ME, Gabbert KC, Mazgaj PW, Wolf MT. Multidose vial contamination in anesthesia. *Aana J* 1990;58:462-6.
241. Falchuk KH, Peterson L, McNeil BJ. Microparticulate-induced phlebitis: its prevention by in-line filtration. *N Engl J Med* 1985;312:78-82.
242. Cohran J, Larson E, Roach H, Blane C, Pierce P. Effect of intravascular surveillance and education program on rates of nosocomial bloodstream infections. *Heart Lung* 1996;25:161-4.
243. Netto dos Santos KR, de Souza Fonseca L, Gontijo Filho PP. Emergence of high-level mupirocin resistance in methicillin-resistant *Staphylococcus aureus* isolated from Brazilian university hospitals. *Infect Control Hosp Epidemiol* 1996;17:813-6.
244. Ryder MA. Peripheral access options. *Surg Oncol Clin N Am* 1995;4:395-427.
245. Maki DG, Goldman DA, Rhame FS. Infection control in intravenous therapy. *Ann Intern Med* 1973;79:867-87.
246. Tager IB, Ginsberg MB, Ellis SE, et al. An epidemiologic study of the risks associated with peripheral intravenous catheters. *Am J Epidemiol* 1983;118:839-51.
247. Horan TC, Emori TG. Definitions of key terms used in the NNIS System. *Am J Infect Control* 1997;25:112-6.
248. Khuri-Bulos NA, Shennak M, Agabi S, et al. Nosocomial infections in the intensive care units at a university hospital in a developing country: comparison with National Nosocomial Infections Surveillance intensive care unit rates. *Am J Infect Control* 1999;27:547-52.
249. Pittet D, Wenzel RP. Nosocomial bloodstream infections. Secular trends in rates, mortality, and contribution to total hospital deaths. *Arch Intern Med* 1995;155:1177-84.
250. CDC. Monitoring hospital-acquired infections to promote patient safety—United States, 1990-1999. *MMWR* 2000;49:149-53.
251. Clark-Christoff N, Watters VA, Sparks W, Snyder P, Grant JP. Use of triple-lumen subclavian catheters for administration of total parenteral nutrition. *J Parenter Enteral Nutr* 1992;16:403-7.
252. Early TF, Gregory RT, Wheeler JR, Snyder SO Jr., Gayle RG. Increased infection rate in double-lumen versus single-lumen Hickman catheters in cancer patients. *South Med J* 1990;83:34-6.
253. Hilton E, Haslett TM, Borenstein MT, Tucci V, Isenberg HD, Singer C. Central catheter infections: single- versus triple-lumen catheters: influence of guide wires on infection rates when used for replacement of catheters. *Am J Med* 1988;84:667-72.
254. Yeung C, May J, Hughes R. Infection rate for single lumen v triple lumen subclavian catheters. *Infect Control Hosp Epidemiol* 1988;9:154-8.
255. Collin GR. Decreasing catheter colonization through the use of an antiseptic-impregnated catheter: a continuous quality improvement project. *Chest* 1999;115:1632-40.
256. Groeger JS, Lucas AB, Thaler HT, et al. Infectious morbidity associated with long-term use of venous access devices in patients with cancer. *Ann Intern Med* 1993;119:1168-74.
257. Pegues D, Axelrod P, McClarren C, et al. Comparison of infections in Hickman and implanted port catheters in adult solid tumor patients. *J Surg Oncol* 1992;49:156-62.
258. Moss AH, Vasilakis C, Holley JL, Foulks CJ, Pillai K, McDowell DE. Use of a silicone dual-lumen catheter with a Dacron cuff as a long-term vascular access for hemodialysis patients. *Am J Kidney Dis* 1990;16:211-5.
259. Schillinger F, Schillinger D, Montagnac R, Milcent T. Post catheterization vein stenosis in haemodialysis: comparative angiographic study of 50 subclavian and 50 internal jugular accesses. *Nephrol Dial Transplant* 1991;6:722-4.
260. Cimochoowski GE, Worley E, Rutherford WE, Sartain J, Blondin J, Harter H. Superiority of the internal jugular over the subclavian access for temporary dialysis. *Nephron* 1990;54:154-61.
261. Barrett N, Spencer S, McIvor J, Brown EA. Subclavian stenosis: a major complication of subclavian dialysis catheters. *Nephrol Dial Transplant* 1988;3:423-5.

262. Terrotola SO, Kuhn-Fulton J, Johnson MS, Shah H, Ambrosius WT, Kneebone PH. Tunneled infusion catheters: increased incidence of symptomatic venous thrombosis after subclavian versus internal jugular venous access. *Radiology* 2000;217:89–93.
263. Macdonald S, Watt AJ, McNally D, Edwards RD, Moss JG. Comparison of technical success and outcome of tunneled catheters inserted via the jugular and subclavian approaches. *J Vasc Interv Radiol* 2000;11:225–31.
264. Widmer AF. Management of catheter-related bacteremia and fungemia in patients on total parenteral nutrition. *Nutrition* 1997;13(suppl):S18–S25.
265. Powell C, Kudsk KA, Kulich PA, Mandelbaum JA, Fabri PJ. Effect of frequent guidewire changes on triple-lumen catheter sepsis. *J Parenter Enteral Nutr* 1988;12:462–4.
266. Snyderman DR, Murray SA, Kornfeld SJ, Majka JA, Ellis CA. Total parenteral nutrition-related infections: prospective epidemiologic study using semiquantitative methods. *Am J Med* 1982;73:695–9.
267. Easom A. Prophylactic antibiotic lock therapy for hemodialysis catheters. *Nephrol Nurs J* 2000;27:75.
268. Vercaigne LM, Sitar DS, Penner SB, Bernstein K, Wang GQ, Burczynski FJ. Antibiotic-heparin lock: in vitro antibiotic stability combined with heparin in a central venous catheter. *Pharmacotherapy* 2000;20:394–9.
269. Donowitz LG, Marsik FJ, Hoyt JW, Wenzel RP. *Serratia marcescens* bacteremia from contaminated pressure transducers. *JAMA* 1979;242:1749–51.
270. Luskin RL, Weinstein RA, Nathan C, Chamberlin WH, Kabins SA. Extended use of disposable pressure transducers: a bacteriologic evaluation. *JAMA* 1986;255:916–20.
271. Maki DG, Hassemer CA. Endemic rate of fluid contamination and related septicemia in arterial pressure monitoring. *Am J Med* 1981;70:733–8.
272. Mermel LA, Maki DG. Epidemic bloodstream infections from hemodynamic pressure monitoring: signs of the times. *Infect Control Hosp Epidemiol* 1989;10:47–53.
273. Tenold R, Priano L, Kim K, Rourke B, Marrone T. Infection potential of nondisposable pressure transducers prepared prior to use. *Crit Care Med* 1987;15:582–3.
274. Leroy O, Billiau V, Beuscart C, et al. Nosocomial infections associated with long-term radial artery cannulation. *Intensive Care Med* 1989;15:241–6.
275. Fisher MC, Long SS, Roberts EM, Dunn JM, Balsara RK. *Pseudomonas maltophilia* bacteremia in children undergoing open heart surgery. *JAMA* 1981;246:1571–4.
276. Stamm WE, Colella JJ, Anderson RL, Dixon RE. Indwelling arterial catheters as a source of nosocomial bacteremia: an outbreak caused by *Flavobacterium* species. *N Engl J Med* 1975;292:1099–102.
277. Weinstein RA, Emori TG, Anderson RL, Stamm WE. Pressure transducers as a source of bacteremia after open heart surgery: report of an outbreak and guidelines for prevention. *Chest* 1976;69:338–44.
278. Shinozaki T, Deane RS, Mazuzan JE Jr., Hamel AJ, Hazelton D. Bacterial contamination of arterial lines: a prospective study. *JAMA* 1983;249:223–5.
279. Solomon SL, Alexander H, Eley JW, et al. Nosocomial fungemia in neonates associated with intravascular pressure-monitoring devices. *Pediatr Infect Dis* 1986;5:680–5.
280. Weems JJ Jr., Chamberland ME, Ward J, Willy M, Padhye AA, Solomon SL. *Candida parapsilosis* fungemia associated with parenteral nutrition and contaminated blood pressure transducers. *J Clin Microbiol* 1987;25:1029–32.
281. Beck-Sague CM, Jarvis WR, Brook JH, et al. Epidemic bacteremia due to *Acinetobacter baumannii* in five intensive care units. *Am J Epidemiol* 1990;132:723–33.
282. Villarino ME, Jarvis WR, O'Hara C, Bresnahan J, Clark N. Epidemic of *Serratia marcescens* bacteremia in a cardiac intensive care unit. *J Clin Microbiol* 1989;27:2433–6.
283. Boo NY, Wong NC, Zulkifli SS, Lye MS. Risk factors associated with umbilical vascular catheter-associated thrombosis in newborn infants. *J Paediatr Child Health* 1999;35:460–5.
284. Cronin WA, Germanson TP, Donowitz LG. Intravascular catheter colonization and related bloodstream infection in critically ill neonates. *Infect Control Hosp Epidemiol* 1990;11:301–8.
285. Miller KL, Coen PE, White WJ, Hurst WJ, Achey BE, Lang CM. Effectiveness of skin absorption of tincture of I in blocking radioiodine from the human thyroid gland. *Health Phys* 1989;56:911–4.
286. Ankola PA, Atakent YS. Effect of adding heparin in very low concentration to the infusate to prolong the patency of umbilical artery catheters. *Am J Perinatol* 1993;10:229–32.
287. Horgan MJ, Bartoletti A, Polansky S, Peters JC, Manning TJ, Lamont BM. Effect of heparin infusates in umbilical arterial catheters on frequency of thrombotic complications. *J Pediatr* 1987;111:774–8.
288. David RJ, Merten DF, Anderson JC, Gross S. Prevention of umbilical artery catheter clots with heparinized infusates. *Dev Pharmacol Ther* 1981;2:117–26.
289. Fletcher MA, Brown DR, Landers S, Seguin J. Umbilical arterial catheter use: report of an audit conducted by the Study Group for Complications of Perinatal Care. *Am J Perinatol* 1994;11:94–9.
290. Seguin J, Fletcher MA, Landers S, Brown D, Macpherson T. Umbilical venous catheterizations: audit by the Study Group for Complications of Perinatal Care. *Am J Perinatol* 1994;11:67–70.
291. Loisel DB, Smith MM, MacDonald MG, Martin GR. Intravenous access in newborn infants: impact of extended umbilical venous catheter use on requirement for peripheral venous lines. *J Perinatol* 1996;16:461–6.
292. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. *Am J Infect Control* 1988;16:128–40.
293. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. Erratum. *Am J Infect Control* 1988;16:177.

Appendix A

Examples of Clinical Definitions for Catheter-Related Infections

Localized Catheter Colonization

Significant growth of a microorganism (>15 CFU) from the catheter tip, subcutaneous segment of the catheter, or catheter hub

Exit Site Infection

Erythema or induration within 2 cm of the catheter exit site, in the absence of concomitant bloodstream infection (BSI) and without concomitant purulence

Clinical Exit Site Infection (Or Tunnel Infection)

Tenderness, erythema, or site induration >2 cm from the catheter site along the subcutaneous tract of a tunneled (e.g., Hickman or Broviac) catheter, in the absence of concomitant BSI

Pocket Infection

Purulent fluid in the subcutaneous pocket of a totally implanted intravascular catheter that might or might not be associated with spontaneous rupture and drainage or necrosis of the overlying skin, in the absence of concomitant BSI

Infusate-Related BSI

Concordant growth of the same organism from the infusate and blood cultures (preferably percutaneously drawn) with no other identifiable source of infection

Catheter-Related BSI

Bacteremia/fungemia in a patient with an intravascular catheter with at least one positive blood culture obtained from a peripheral vein, clinical manifestations of infections (i.e., fever, chills, and/or hypotension), and no apparent source for the BSI except the catheter. One of the following should be present: a positive semiquantitative (>15 CFU/catheter segment) or quantitative (>10³ CFU/catheter segment catheter) culture whereby the same organism (species and antibiogram) is isolated from the catheter segment and peripheral blood; simultaneous quantitative blood cultures with a \geq 5:1 ratio CVC versus peripheral; differential period of CVC culture versus peripheral blood culture positivity of >2 hours.

Surveillance Definitions for Primary BSIs, National Nosocomial Infections Surveillance System

Laboratory-Confirmed BSI

Should meet at least one of the following criteria:

Criterion 1: Patient has a recognized pathogen cultured from one or more blood cultures, and the pathogen cultured from the blood is not related to an infection at another site.

Criterion 2: Patient has at least one of the following signs or symptoms: fever (>100.4° F [>38° C]), chills, or hypotension, and at least one of the following:

1. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from two or more blood cultures drawn on separate occasions.
2. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from at least one blood culture from a patient with an intravenous line, and the physician institutes appropriate antimicrobial therapy.
3. Positive antigen test on blood (e.g., *Hemophilus influenzae*, *Streptococcus pneumoniae*, *Neisseria meningitides*, or group B streptococcus).

and signs and symptoms with positive laboratory results are not related to an infection at another site.

Criterion 3: Patient aged <1 year has at least one of the following signs or symptoms: fever (>100.4° F [>38° C]), hypothermia (<98.6° F [<37° C]), apnea, or bradycardia, and at least one of the following:

1. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from two or more blood cultures drawn on separate occasions.
2. Common skin contaminant (e.g., diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci) cultured from at least one blood culture from a patient with an intravenous line, and the physician institutes appropriate antimicrobial therapy.
3. Positive antigen test on blood (e.g., *Hemophilus influenzae*, *Streptococcus pneumoniae*, *Neisseria meningitides*, or group B streptococcus).

and signs and symptoms with positive laboratory results are not related to an infection at another site.

Clinical Sepsis

Should meet at least one of the following criteria:

Criterion 1: Patient has at least one of the following clinical signs with no other recognized cause: fever ($>100.4^{\circ}\text{F}$ [$>38^{\circ}\text{C}$]), hypotension (systolic pressure <90 mm Hg), or oliguria (<20 mL/hr), and blood culture not done or no organisms or antigen detected in blood and no apparent infection at another site, and physician institutes treatment for sepsis.

Criterion 2: Patient aged <1 year has at least one of the following clinical signs or symptoms with no other recognized cause: fever ($>100.4^{\circ}\text{F}$ [$>38^{\circ}\text{C}$]), hypothermia ($<98.6^{\circ}\text{F}$ [$<37^{\circ}\text{C}$]), apnea, or bradycardia, and blood culture not done or no organisms or antigen detected in blood and no apparent infection at another site, and physician institutes treatment for sepsis.

Catheter-Associated BSI

Defined by the following:

- Vascular access device that terminates at or close to the heart or one of the great vessels. An umbilical artery or vein catheter is considered a central line.
- BSI is considered to be associated with a central line if the line was in use during the 48-hour period before development of the BSI. If the time interval between onset of infection and device use is >48 hours, there should be compelling evidence that the infection is related to the central line.

Arterial or Venous Infection

Included are arteriovenous graft, shunt, fistula, or intravenous cannulation. Should meet at least one of the following criteria:

Criterion 1: Patient has organisms cultured from arteries or veins removed during a surgical operation and blood culture not done or no organisms cultured from blood.

Criterion 2: Patient has evidence of arterial or venous infection seen during a surgical operation or histopathologic examination.

Criterion 3: Patient has at least one of the following signs or symptoms with no other recognized cause: fever ($>100.4^{\circ}\text{F}$ [$>38^{\circ}\text{C}$]), pain, erythema, or heat at involved vascular site and >15 CFUs cultured from an intravascular cannula tip using a semiquantitative culture method and blood culture not done or no organisms cultured from blood.

Criterion 4: Patient has purulent drainage at the involved vascular site and blood culture not done or no organisms cultured from blood.

Criterion 5: Patient aged <1 year has at least one of the following signs or symptoms with no other recognized cause: fever ($>100.4^{\circ}\text{F}$ [$>38^{\circ}\text{C}$]), hypothermia ($<98.6^{\circ}\text{F}$ [$<37^{\circ}\text{C}$]), apnea, bradycardia, lethargy, or pain, erythema or heat at involved vascular site and >15 colonies cultured from intravascular cannula tip using semiquantitative method and blood culture not done or no organisms cultured from blood.

Appendix B

Summary of Recommended Frequency of Replacements for Catheters, Dressings, Administration Sets, and Fluids

Catheter	Replacement and relocation of device	Replacement of catheter site dressing	Replacement of administration sets	Hang time for parenteral fluids
Peripheral venous catheters	Replacement and relocation of device	Replace dressing when the catheter is removed or replaced, or when the dressing becomes damp, loosened, or soiled. Replace dressings more frequently in diaphoretic patients. In patients who have large bulky dressings that prevent palpation or direct visualization of the catheter insertion site, remove the dressing and visually inspect the catheter at least daily and apply a new dressing.	Replace intravenous tubing, including add-on devices, no more frequently than at 72-hour intervals unless clinically indicated. Replace tubing used to administer blood, blood products, or lipid emulsions within 24 hours of initiating the infusion. <i>No recommendation</i> for replacement of tubing used for intermittent infusions. Consider short extension tubing connected to the catheter to be a portion of the device. Replace such extension tubing when the catheter is changed.	<i>No recommendation</i> for the hang time of intravenous fluids, including nonlipid-containing parenteral nutrition fluids. Complete infusion of lipid-containing parenteral nutrition fluids (e.g., 3-in-1 solutions) within 24 hours of hanging the fluid. Complete infusion of lipid emulsions alone within 12 hours of hanging the fluid. Complete infusions of blood products within 4 hours of hanging the product.
Midline catheters	In adults, replace catheter and rotate site no more frequently than every 72–96 hours. Replace catheters inserted under emergency basis and insert a new catheter at a different site within 48 hours. In pediatric patients, do not replace peripheral catheters unless clinically indicated.	As above.	As above.	As above.
Peripheral arterial catheters	<i>No recommendation</i> for the frequency of the catheter replacement.	Replace dressing when the catheter is replaced, or when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary.	Replace the intravenous tubing at the time the transducer is replaced (i.e., 72-hour intervals).	Replace the flush solution at the time the transducer is replaced (i.e., 72-hour intervals).
Central venous catheters including peripherally inserted central catheters and hemodialysis catheters	In adults, do not replace catheters routinely to prevent catheter-related infection. In pediatric patients, <i>no recommendation</i> for the frequency of catheter replacement. Replace disposable or reusable transducers at 72-hour intervals. Replace continuous flush device at the time the transducer is replaced.	Replace gauze dressings every 2 days and transparent dressings every 7 days on short-term catheters. Replace the dressing when the catheter is replaced, or when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary.	Replace intravenous tubing and add-on devices no more frequently than at 72-hour intervals. Replace tubing used to administer blood products or lipid emulsions within 24 hours of initiating the infusion.	<i>No recommendation</i> for the hang time of intravenous fluids, including nonlipid-containing parenteral nutrition fluids. Complete infusions of lipid-containing fluids within 24 hours of hanging the fluid.
Pulmonary artery catheters	Do not routinely replace catheters.	As above.	As above.	As above.
Umbilical catheters	Do not replace catheter to prevent catheter-related infection. Do not routinely replace catheters.	Not applicable.	Replace intravenous tubing and add-on devices no more frequently than at 72-hour intervals. Replace tubing used to administer blood products or lipid emulsions within 24 hours of initiating the infusion.	<i>No recommendation</i> for the hang time of intravenous fluids, including nonlipid-containing parenteral nutrition fluids. Complete infusion of lipid-containing fluids within 24 hours of hanging the fluid. Includes nontunneled catheters, tunneled catheters, and totally implanted devices.

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