Disinfection and Sterilization

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The Emerging Nosocomial Pathogens *Cryptosporidium*, *Escherichia coli* O157:H7, *Helicobacter pylori*, and Hepatitis C: Epidemiology, Environmental Survival, Efficacy of Disinfection, and Control Measures

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ABSTRACT

New and emerging infectious diseases pose a threat to public health and may be responsible for nosocomial outbreaks. *Cryptosporidium parvum* and *Escherichia coli* are gastrointestinal pathogens that have caused nosocomial infections via person-to-person transmission, environmental contamination, or contaminated water or food. *Helicobacter pylori* has been transmitted via inadequately disinfected endoscopes. Finally, hepatitis C may be acquired by healthcare personnel by percutaneous or mucous membrane exposure to blood or between patients by use of contaminated blood products or via environmental contamination. Rigorous adherence to Standard Precautions, Contact Precautions for patients with infectious diarrhea, disinfection of environmental surfaces, and appropriate disinfection of endoscopes are adequate to prevent nosocomial acquisition of these pathogens (*Infect Control Hosp Epidemiol* 2001;22:306-315).

The 1992 report by the Institute of Medicine, "Emerging Infections: Microbial Threats to Health in the United States," called attention to the threats posed by new and emerging infectious diseases.[1] The multiple reasons for the emergence of new infectious diseases or increasing incidence of previously described agents have been well described in review articles.[2,3] Infection control professionals must deal with new and emerging nosocomial pathogens. The reasons for the emergence of new nosocomial pathogens include enhanced survival of immunocompromised hosts, acquisition and spread of adaptive genes (ie, antibiotic resistance and virulence genes), enhanced ability to survive in new ecologic niches, increasing use of invasive procedures, unrecognized virulence, prior under-identification due to difficulties in culturing, and increased recognition due to taxonomic clarification.[4]

This article will review the epidemiology, environmental survival, efficacy of disinfection and sterilization, and control measures of several emerging nosocomial pathogens: *Cryptosporidium parvum, Escherichia coli* O157:H7, *Helicobacter pylori,* and hepatitis C.

CRYPTOSPORIDIUM SPECIES

Epidemiology and Nosocomial Significance

C parvum, a protozoa belonging to the suborder Eimeriina, is a well-recognized cause of gastroenteritis in both immune-compromised[5,6] and immune-competent persons.[7] Infection is acquired via ingestion of cryptosporidial cysts and has been linked to potable water[8]; ingestion of contaminated food[9,10]; drinking unpasteurized apple juice[11]; recreational water activities, including swimming pools,[8,12,13] lakes,[8] and water parks[14]; close person-to-person contact[7]; and contact with farm animals.[15]

Cryptosporidiosis represents an important emerging highly infectious pathogen for the following reasons.[16-19] First, it is a common cause of self-limited gastroenteritis in the normal host and can cause potentially life-threatening disease in immunocompromised persons. Second, it is a highly infectious enteric pathogen. Based on human volun-

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01-SX-015. Weber DJ, Rutala WA. The emerging nosocomial pathogens Cryptosporidium, Escherichia coli *O157:H7,* Helicobacter pylori, *and hepatitis C: epidemiology, environmental survival, efficacy of disinfection, and control measures.* Infect Control Hosp Epidemiol *2001;22:306-315.*

teer studies, the dose necessary to infect 50% of those exposed (ID_{50}) has been estimated at only 132 oocysts; some infections followed the ingestion of only 30 oocysts,[20] and infections after the ingestion of a single oocyst have been reported.[21] Third, it is persistent in water and resistant to chlorine at levels used in potable and swimming-pool water.[22,23] Fourth, it is ubiquitous in many feral, domestic, and agricultural animals, representing a major threat to the water supply in the United States. The small dose required for infection, the fecal-oral route of transmission, and prolonged environmental survival in water allows *Cryptosporidium* to spread in households, healthcare facilities, and child-care centers.

Nosocomial transmission has been reported.[24-30] Direct[24,25] and indirect[26-28] person-to-person transmission (via contaminated hands) has been incriminated as the likely mechanism of transmission. In addition, ice contaminated by a patient has led to an outbreak among patients and staff.[29] Multiple outbreaks have been reported in child-care centers.[31-34] Outbreaks in veterinary facilities have involved students and staff.[35]

Cryptosporidium poses significant challenges to public health and water authorities.[36] Large outbreaks of cryptosporidiosis associated with contaminated drinking water have occurred in Milwaukee[37] and Las Vegas.[38] Overall, cryptosporidiosis accounted for more than 70% of illnesses associated with drinking water outbreaks reported to the Centers for Disease Control and Prevention (CDC) between 1997 and 1998.[8]

Environmental Survival

C parvum is capable of surviving for long periods of time when immersed in water. First-order kinetics of die-off rates of *C parvum* experimentally exposed to natural river water ranged from 0.013 to 0.039 $\log_{10}$ per day.[39] Die-off was higher in natural river water than in synthetic hard water.[39]

The survival of *C parvum* on experimentally contaminated environmental surfaces has been examined. Robertson et al used a vital dye test to evaluate *C parvum* oocyst survival on surfaces at room temperature and observed 97% loss of viability by 2 hours and 100% by 4 hours.[40] Barbee and colleagues, using a viability assay, reported the following decreases in infective *C parvum* oocysts with time: 30 minutes, 2.9-$\log_{10}$; 60 minutes, 3.8-$\log_{10}$; and 90 minutes, >4.0-$\log_{10}$.[41] More prolonged survival has been reported when *Cryptosporidium* in a diarrheal stool is applied to an environmental surface; Anderson noted that *Cryptosporidium* in a diarrheal stool smeared on a wooden surface survived for up to 72 hours.[42]

Efficacy of Disinfection and Sterilization

Cryptosporidium is relatively resistant to chlorine at concentrations used in potable water. *C parvum* is not completely inactivated by most disinfectants used in health care, including ethyl alcohol,[41] glutaraldehyde,[41,43] 5.25% hypochlorite,[41] peracetic acid,[41] ortho-phthalaldehyde,[41] phenol,[41,43] povidone-iodine,[41-43] and quaternary ammonium compounds[41] (Table 1). The only chemical disinfectants or sterilants able to inactivate greater than 3 $\log_{10}$ of *C parvum* were 6% and 7% hydrogen peroxide.[41] Sterilization methods that will fully inactivate *C parvum* include steam,[41] ethylene oxide,[41,44] and the Sterrad 100.[41]

TABLE 1
EFFICACY OF DISINFECTION METHODS AGAINST *CRYPTOSPORIDIUM PARVUM*

Ineffective Methods
Quaternary ammonium (use dilution, 20°C, 10 min)
Hypochlorite (5.25%, 20°C, 10 min)
Phenolic (use dilution, 20°C, 10 min)
Iodophor (1%, 20°C, 20 min)
Ethyl alcohol (70%, 20°C, 20 min)
Hydrogen peroxide (3%, 20°C, 10 min)
Hydrogen peroxide (3%, 20°C, 20 min)
Hydrogen peroxide (6%, 20°C, 10 min)
Glutaraldehyde (2.4%, 25°C, 45 min)
Peracetic acid (0.35%, 20°C, 20 min)
Peracetic acid (0.2%, 50°C, 12 min)
Peracetic acid (0.2%, 23-25°C, 12 min)
Ortho-phthalaldehyde (undiluted, 20°C, 20 min)
Effective Methods
Hydrogen peroxide (6%, 20°C, 20 min)*
Hydrogen peroxide (7.5%, 20°C, 20 min)*

* >3-log kill.

Control Measures

The major threat posed by *Cryptosporidium* in the hospital is the acquisition of infection by immunocompromised patients via ingestion of contaminated potable water. The CDC has recommended that human immunodeficiency virus (HIV)-infected persons who wish to take independent action to reduce risk for waterborne cryptosporidiosis may choose to take precautions similar to those recommended during outbreaks (ie, ingest water that has been boiled for 1 minute or filtered through a submicron filter).[45] Recently the CDC recommended that hematopoietic stem cell transplant (HSCT) recipients should avoid the following activities to prevent exposure to *Cryptosporidium:* walking, wading, swimming, or playing in recreational water likely to be contaminated with *Cryptosporidium,* sewage, or animal or human wastes; ingesting water taken directly from rivers and lakes; and use of water from private wells or public wells in communities with limited populations.[46] To eliminate the risk of *Cryptosporidium* from tap water completely, HSCT recipients can either boil or filter the water. Similar recommendations have been published in England.[47] It would be prudent for hospitals to provide all immunocompromised persons (eg, due to chemotherapy or being IgA deficient or HIV-infected) with sterile water and ice for ingestion.

Patients with cryptosporidiosis can be managed using Standard Precautions.[48] This CDC recommendation recently was validated by a retrospective cohort study of 37

TABLE 2
EFFICACY OF DISINFECTION METHODS AGAINST *ESCHERICHIA COLI* O157:H7

Effective Methods
Quaternary ammonium (use dilution, 20°C, 0.5 min)*
Hypochlorite (0.525%, 20°C, 0.5 min)*
Phenolic (use dilution, 20°C, 0.5 min)*
Ethyl alcohol (70%, 20°C, 0.5 min)*

*> 5-log kill.

hospitalized patients, which failed to identify roommate-to-roommate transmission of *Cryptosporidium.*[49] Contact Precautions should be used for diapered or incontinent children less than 6 years of age for the duration of the illness. HIV-infected patients, especially those who are severely immunocompromised, should not share a room with persons infected with *Cryptosporidium.*[45]

Current hospital cleaning practices appear satisfactory to prevent nosocomial transmission. Chest-type ice machines should not be used in clinical areas of the hospital to prevent possible contamination.[29] Endoscopes are unlikely to represent an important vehicle for the cross-transmission of *C parvum,* because mechanical cleaning will remove approximately 10^4 organisms, and rapid drying results in loss of *C parvum* viability.[41]

ESCHERICHIA COLI O157:H7

Epidemiology and Nosocomial Significance

There has been growing appreciation of the major public health impact of foodborne diseases[50-53] and the importance of *E coli* O157:H7 as a foodborne pathogen.[54,55] *E coli* O157:H7 was first recognized as a human pathogen in 1982, when two outbreaks in the United States were associated with eating undercooked hamburgers.[56,57] Currently, *E coli* O157:H7 is estimated to result annually in 20,000 cases of gastroenteritis and 100 to 200 deaths.[51] *E coli* O157:H7 is transmitted from its bovine reservoir to humans via direct contact or via contaminated water or food.[58] Raw or undercooked meat has been the food item most commonly associated with outbreaks of *E coli* O157:H7, but infection has followed ingestion of other contaminated foods, including vegetables such as lettuce and radish sprouts; unpasteurized juice, milk, or cheese; and water.[59,60] Secondary person-to-person transmission may occur following initial human infection; the household transmission rate has been calculated to be 4% to 15%.[61] Person-to-person transmission is facilitated by the low inoculum dose required for infection. In two outbreak investigations, the infectious dose of *E coli* O157:H7 was found to be fewer than 700 organisms[62] and fewer than 50 organisms.[63]

Nosocomial outbreaks of *E coli* O157:H7 have been reported occasionally.[64-68] Evaluations of these outbreaks have suggested direct person-to-person transmission,[65-68] indirect transmission via environmental contamination,[68] and contaminated food (lettuce).[66] Transmission from patients to staff has been reported, but the number of staff infected in such incidents usually is low.[67,68] Outbreaks also have been reported in child-care centers[69-71] and extended-care facilities.[72,73] In some reported outbreaks, it has not been possible to establish if staff have acquired infection from eating the same implicated food or secondarily from patients.[66-73]

Environmental Survival

E coli O157:H7 is capable of surviving for prolonged periods of time in soil, meats, and produce. For example, *E coli* O157:H7 was capable of surviving for up to 144 hours in untreated milk held at 7°C without a change in colony counts, but when held at 15°C a 3.7-$\log_{10}$ increase was noted.[74] When inoculated into chicken manure, *E coli* O157:H7 demonstrated a 1- to 2-$\log_{10}$ increase over a period of 2 days at 20°C.[75] Drying of the manure to 10% moisture at 20°C resulted in 1- to 2-$\log_{10}$ decrease in counts over 24 hours. When inoculated onto lettuce, *E coli* O157:H7 was demonstrated to survive at 4°C for up to 15 days.[76]

Efficacy of Disinfection and Sterilization

Disinfectants, including chlorine compounds, are unable to eliminate *E coli* O157:H7 experimentally inoculated onto alfalfa seeds or sprouts[77,78] or beef-carcass surfaces.[79] However, chlorine at approximately 1 ppm has been found capable of eliminating approximately 4 $\log_{10}$ of *E coli* O157:H7 within 1 minute in a suspension test.[80]

Electrolyzed oxidizing water at 23°C was effective in 10 minutes in producing a 5-$\log_{10}$ decrease in *E coli* O157:H7 inoculated onto kitchen cutting boards.[81] The following disinfectants were effective in eliminating >5 $\log_{10}$ of *E coli* O157:H7 within 30 seconds: a quaternary ammonium compound, a phenolic, a hypochlorite (1:10 dilution of 5.25% bleach), and ethanol[82] (Table 2).

Control Measures

E coli represents an important public health threat. Consumers are advised to follow food-safety guidelines.[83] These include thorough heating of potentially hazardous foods and prompt refrigeration of used foods. Additional measures include separating cooked and raw foods and preventing contamination of cooked foods by drippings from raw foods. Contaminated surfaces (eg, cutting boards) should be washed. Consumers should consider avoiding high-risk foods such as raw or runny eggs and undercooked hamburger meat (ie, pink or red in center). Raw sprouts should not be consumed by the elderly, children, and those with a compromised immune system.[84]

Patients infected with *E coli* O157:H7 can be managed using Standard Precautions.[48] Contact Precautions should be used for diapered or incontinent children less than 6 years of age for the duration of the illness. Standard hospital surface disinfectants are adequate for inactivating *E coli* O157:H7 and can be used for terminal cleaning or cleaning of contaminated surfaces. Current

guidelines for the disinfection of endoscopes should be followed.

HELICOBACTER PYLORI

Epidemiology and Nosocomial Significance

H pylori is a fastidious, microaerophilic, spiral-shaped, gram-negative rod. First isolated in 1983,[85,86] *H pylori* is now known to play an important role in the development of gastritis, peptic ulcer disease, distal gastric adenocarcinoma, and gastric lymphoma.[87-89] The incidence of *H pylori* infection in developed countries has been estimated to be approximately 0.5%, with the incidence decreasing over time.[90]

The route of *H pylori* transmission remains a topic of intense controversy because of incomplete information, including how the organism leaves its host and enters the environment, where (if anywhere) the organism persists in the environment, how people become infected, and whether all persons are susceptible to infection.[88,91] Circumstantial evidence suggests that the most likely means of *H pylori* transmission is direct person-to-person spread. This may occur via fecal-oral, oral-oral, or gastric-oral routes. Fecal-oral transmission is suggested by the finding of higher prevalence rates of infection in crowded households, institutions for the disabled, or households with young children.[88] Fecal-oral transmission is supported by the occasional isolation of *H pylori* from the stools of adults[92,93] and children.[92] Oral-oral transmission is suggested by the ability to detect *H pylori* DNA by polymerase chain reaction (PCR) from both saliva and dental plaque, although viable *H pylori* have only occasionally been isolated from the mouth.[94] Gastric-oral transmission has been suggested by iatrogenic transmission of *H pylori* in endoscopy suites (see below). Epidemiological studies of Peruvian children have shown that *H pylori* infection is associated with consuming food from street vendors[95] and drinking potable water from community wells,[96] thus suggesting transmission via contaminated food and water.

Nosocomial transmission of *H pylori* via inadequately cleaned and disinfected medical equipment, most commonly endoscopes, has been suggested by epidemiological investigations and demonstrated by molecular techniques.[97] *H pylori* has been isolated from used endoscopes and biopsy forceps.[98] Epidemic gastritis with hypochlorhydria, a syndrome compatible with *H pylori* infection, has been reported following the use on multiple patients of pH electrodes that were not disinfected between patients.[99,100] Epidemiological investigations have suggested cross-transmission of *H pylori* by potentially contaminated endoscopes.[101-103] Patient-to-patient transmission of *H pylori* via contaminated endoscopes has been proven by use of molecular techniques[104,105]; all cases of transmission have followed the use of ineffective disinfectants such as 70% ethanol[103,104] or 0.2% benzethonium chloride.[101]

Mouth-to-mouth transmission has been reported to lead to acquisition of *H pylori*.[106] A sero-epidemiological study demonstrated that endoscopy personnel had a higher prevalence of *H pylori* than blood donors, raising the potential that *H pylori* was an occupational hazard.[107] However, the use of a highly screened population (ie, blood donors) as a control group may have been inappropriate. Further, seropositivity was not associated with years involved in endoscopy or number of endoscopies performed monthly.

Environmental Survival

Data on the environmental survival of *H pylori* is limited. *H pylori* can change from its normal rod-like appearance into a range of coccoidal forms, especially after antibiotic treatment or in vitro after prolonged culture. In the coccoidal form, *H pylori* cannot be grown in culture, and thus it is believed that the hypothesis that *H pylori* is a zoonosis or transmitted as coccoid forms by vectors (pets, houseflies) is not supported by recent research.[108] It also is unknown whether the coccoidal forms can revert to the spiral, multiplying forms. However, Cellini and colleagues demonstrated in a rodent model that administration of the coccoid form of *H pylori* resulted in infection.[109] The viability of the coccoidal forms represents an important scientific question bearing on the potential infectivity of contaminated water and food, and the role of the environment in transmission of *H pylori.*

In an early experiment, the median survival of *H pylori* in distilled water or saline was found to be only 0 to 2 days.[110] Using a higher titer of *H pylori,* Shahamat demonstrated that *H pylori* could survive for 48 hours in sterile river water at 4°C; in some cases, viable bacteria were culturable for up to 20 to 30 days, depending on physical conditions of the environment.[111] *H pylori* is capable of surviving for up to 10 days in milk at 4°C and 4 days in tap water, with a steady decrease in colony-forming units; the nonculturable coccoid form was present at 7 days in tap water kept at 4°C.[112] *H pylori* DNA has been detected by PCR in 12% to 36% of potable-water sites (private wells, municipal tap water, wastewater) tested in Sweden[113] and in samples of tap water, well water, and field soil in Japan.[114]

The survival of *H pylori* on environmental surfaces has not been determined.

Efficacy of Disinfection and Sterilization

Only limited data are available on the susceptibility of *H pylori* to disinfectants (Table 3). Using a suspension

TABLE 3
EFFICACY OF DISINFECTION METHODS AGAINST *HELICOBACTER PYLORI*

Effective Methods
Hypochlorite (150 ppm, 25°C, ≤0.5 min)*
Ethyl alcohol (80%, 25°C, 0.25 min)*
Glutaraldehyde (0.5%, 25°C, 0.25 min)*

* >7-log kill.

test, Akamatsu and colleagues assessed the effectiveness of a variety of disinfectants against nine strains of *H pylori*.[115] Ethanol (80%) and glutaraldehyde (0.5%) killed all strains within 15 seconds, whereas chlorhexidine gluconate (0.05% and 1.0%), benzalkonium chloride (0.025% and 0.1%), alkyldiaminoethylglycine hydrochloride (0.1%), povidone-iodine (0.1%), and sodium hypochlorite (150 ppm) killed all strains within 30 seconds. Both ethanol (80%) and glutaraldehyde (0.5%) retained similar bactericidal activity in the presence of organic matter, whereas the other disinfectants showed reduced bactericidal activity. In particular, the bactericidal activities of povidone-iodine (0.1%) and sodium hypochlorite (150 ppm) were markedly decreased in the presence of dried yeast solution, with killing times increased to 5 to 10 minutes and 5 to 30 minutes, respectively.

Immersion of biopsy forceps in formalin prior to obtaining a specimen does not affect the ability to obtain a culture of *H pylori* from the biopsy specimen.[116] The following methods have been demonstrated to be ineffective for eliminating *H pylori* from endoscopes: cleaning with soap and water,[117,118] immersion in 70% ethanol for 3 minutes,[104] instillation of 70% ethanol,[103] instillation of 30 mL of 83% methanol,[117] and 0.2% benzethonium chloride solution.[101] The differing results with regard to the efficacy of ethyl alcohol are unexplained. Cleaning followed by use of 2% alkaline glutaraldehyde has been demonstrated by culture to be effective in eliminating *H pylori*.[117-119] Epidemiological investigations of patients who had undergone endoscopy with scopes mechanically washed and disinfected with 2.0% to 2.3% glutaraldehyde have revealed no evidence of cross-transmission of *H pylori*.[103-120] Disinfection of experimentally contaminated endoscopes using 2% glutaraldehyde (10-m, 20-m, and 45-m exposure times) or the Steris (Steris Corp, Menton, OH) system (with and without active peracetic acid) has been demonstrated to be effective in eliminating *H pylori*.[118] *H pylori* DNA has been detected by PCR in fluid flushed from endoscope channels following cleaning and disinfection with 2% glutaraldehyde.[121] The clinical significance of this finding is unclear.

In vitro experiments have demonstrated a >3.5-$\log_{10}$ reduction in *H pylori* after exposure to 0.5 mg/L of free chlorine for 80 seconds.[122]

Control Measures

H pylori represents an important nosocomial pathogen that commonly contaminates endoscopes and has been transmitted by inadequately cleaned and disinfected scopes. However, cleaning followed by disinfection of endoscopes with ⩾2.0% glutaraldehyde or peracetic acid has been demonstrated to be effective in eliminating *H pylori.* Standard chlorination of potable water appears adequate to eliminate the possibility of transmission via contaminated water. Studies demonstrating an increased risk of *H pylori* among endoscopic personnel are flawed, and additional studies should be undertaken before concluding that such personnel are at increased risk for acquisition of *H pylori*. However, personnel should use Standard Precautions when performing endoscopy.

Although data are lacking regarding the possibility of person-to-person transmission when close contact occurs, the possibility of transmission cannot be ruled out in settings such as child-care centers and institutions caring for mentally disabled children.

HEPATITIS C

Epidemiology and Nosocomial Significance

Hepatitis C (HCV), an RNA virus, is the most common chronic bloodborne infection in the United States. The annual number of new infections in 1996 was 36,000, which represents a decline of more than 80% since 1989.[123] Data from the Third National Health and Nutrition Examination Survey, conducted from 1988 through 1994, indicated that an estimated 1.8% of US residents have been infected with HCV.[124] The estimated prevalence in selected population groups is as follows[123,125]: persons with hemophilia treated with product made before 1987, 87%; current injecting drug users, 79%; chronic hemodialysis patients, 10%; persons reporting a history of sexually transmitted diseases, 6%; infants born to infected mothers, 5%; men who have sex with other men, 4%; and volunteer blood donors, 0.16%. Population-based studies indicate that 40% of chronic liver disease is HCV-related, resulting in an estimated 8,000-10,000 deaths per year.[123]

HCV is transmitted primarily through large or repeated direct percutaneous exposures to blood. The majority of patients infected with HCV in the United States and Europe acquired the disease through transfusion or injecting drug use. Prior to the discovery of HCV in 1989 and the subsequent implementation of an HCV-antibody detection assay for screening of blood donors in 1990, the risk of acquiring HCV through blood transfusion was as high as 1 in 200 units.[126] Following the introduction of improved HCV antibody assays in 1992 and 1996, the risk fell to 1 per 103,000 units of blood.[127] With the introduction of nucleic acid testing in the spring of 1999, it is estimated that the risk of transfusion-transmitted HCV will fall to between 1 in 500,000 and 1 in 1,000,000 units.[126] HCV transmission also was associated with use of tainted clotting-factor concentrates in hemophiliacs,[128] contaminated immunoglobulin preparations used to treat patients with humoral defects,[129-131] contaminated anti-rhesus D preparations used in young women,[132,133] and plasmapheresis.[134,135] Transmission of HCV by infected donor tissue has been demonstrated in kidney, heart, and liver transplantation.[136] In the United States, no association has been found between hepatitis C infection and exposures resulting from medical, surgical, or dental procedures; tattooing, acupuncture, or ear piercing; or foreign travel.[125]

Between 1983/84 and 1995/96, injecting drug use became an increasingly important mechanism of HCV acquisition, accounting for more than 50% of HCV transmission in the United States. However, in parallel with the overall decrease in HCV prevalence, the number of

cases of acute HCV among injecting drug users has declined dramatically since 1989. Currently, injecting drug use accounts for 60% of HCV transmission, sexual contact for 20%, and other known exposures (household, perinatal, occupational) for 10%.[125] In the remaining 10%, no recognized source of infection can be identified, although most persons in the category are associated with low socioeconomic level.

Nosocomial transmission of HCV has been reviewed.[123,137-140] The most important nosocomial source was transfusions of blood products, until the development and implementation of improved screening methods. Hemodialysis patients are at high risk for acquisition of hepatitis C. The prevalence of anti-HCV among dialysis patients ranges from 8% to 36% in the United States[141] and from 1% to 47% worldwide.[142,143] A survey of 2,647 US hemodialysis centers in 1995 by the CDC revealed that the prevalence of anti-HCV was 10.4% among patients.[144] A similar survey of 3,077 centers in 1997 revealed that the prevalence of anti-HCV was 9.3% among the 48% of centers that tested patients for anti-HCV.[145] Patient-to-patient transmission in hemodialysis centers has been confirmed by molecular analysis of HCV strains isolated.[146-152] Studies have consistently demonstrated an association between anti-HCV positivity and increasing years on dialysis, an association that is independent of blood transfusions.[140] Investigation of dialysis-associated outbreaks of hepatitis C indicates that HCV transmission might occur among patients in a hemodialysis center because of incorrect implementation of infection control practices, especially sharing medication vials and supplies.[123] HCV has been detected by PCR on the hands of healthcare personnel caring for hemodialysis patients, despite the use of Standard Precautions.[153]

Nosocomial transmission of HCV has only occasionally been reported in healthcare settings other than hemodialysis. HCV has been transmitted at least twice during colonoscopy.[154,155] The former case was likely due to inadequate cleaning and disinfection of the colonoscope, whereas the latter case was likely due to use of a multidose anesthetic vial or a shared syringe. In addition, HCV has been transmitted during endoscopic retrograde cholangiography.[156] An outbreak on a pediatric oncology ward was felt to be due to contamination of multidose vials.[157] An investigation of institutionalized psychiatric patients revealed a higher-than-expected prevalence of anti-HCV.[158] A case-control study demonstrated the following independent risk factors for infection: duration of hospitalization, age, razor sharing, and history of surgery. On this basis, the authors suggested that razor sharing be avoided.[158] An outbreak of hepatitis C infection confirmed by molecular typing was reported in a fertility clinic during procedures for assisted conception.[159] Despite an extensive investigation, the exact means of cross-transmission was not discovered, and the most likely route of contamination was healthcare workers. Schvarcz and colleagues[160] investigated a cluster of hepatitis C confirmed by phylogenetic analysis among subjects participating in a research project; cross-transmission was felt to result from the failure to adhere strictly to Standard Precautions. Cross-transmission due to contamination of anesthetic circuitry was suggested as the cause of an outbreak of hepatitis C among patients who had undergone surgery in the same operating suite on the same day.[161] This outbreak led to changes in local guidelines for infection control in anesthesiology[162] and generated significant controversy about the potential mode of cross-transmission,[163,164] as well as the need to revise current US infection control guidelines in anesthesiology.[163,164] Lloyd and coworkers subsequently demonstrated that a hydrophobic pleated-membrane breathing circuit filter consistently prevented the passage of hepatitis C virus, whereas a large-pore "electret" filter design was ineffective.[165]

Healthcare workers who frequently have contact with blood are at risk of occupationally acquired infection with bloodborne pathogens. However, the prevalence of HCV infection among healthcare workers is approximately 1% to 2%.[145,166-170] This rate, which includes orthopedic, general, and oral surgeons, and hemodialysis staff, is similar to the rate in the general population. Following a percutaneous injury with a contaminated sharp or a needlestick, the rate of seroconversion among healthcare workers has averaged 1.8% (range, 0% to 7%).[123] One study from Japan, which used reverse transcriptase PCR to detect HCV RNA, reported a seroconversion rate of 10% following contaminated needlestick injuries.[171] Transmission of HCV has followed from blood splashed to conjunctivae.[172,173] No case reports have described HCV transmission following blood exposure of nonintact skin.

Physician-to-patient transmission of HCV has rarely been reported, but three papers reported transmission during surgery.[174-176] In two reports only a single patient was infected, but in one report five patients were infected[175]; molecular typing suggested transmission from the healthcare worker.[175,176]

Environmental Survival

The environmental survival of HCV is unknown. No studies have been conducted for HCV comparable to that conducted by Favero and Bond,[177] which demonstrated that hepatitis B virus remains infectious for at least 1 week on environmental surfaces. As measured by PCR, there is a rapid decline in detectable HCV RNA of 3 to 4 $\log_{10}$ within 14 days when HCV-contaminated whole blood and serum were stored at room temperature.[178]

Efficacy of Disinfection and Sterilization

Using experimentally contaminated hysteroscopes, Sartor and colleagues detected HCV by PCR in 1 (3%) of 34 samples following cleaning with a detergent, but in no samples following treatment with a 2% glutaraldehyde solution for 20 minutes.[179] Rey and colleagues demonstrated complete elimination of hepatitis C virus by PCR from endoscopes used on chronically infected patients following cleaning and disinfection for 3 to 5 minutes in glutaraldehyde.[180] Similarly, Chanzy and coworkers used

PCR to demonstrate complete elimination of HCV following standard disinfection by experimentally contaminated endoscopes.[181]

Control Measures

Transfusions now represent only a minimal risk for the transmission of HCV in healthcare facilities. Nosocomial transmission of HCV is possible if infection control techniques or disinfection procedures are inadequate and contaminated equipment is shared among patients.[123] Fortunately, cases of nosocomial transmission have been reported only rarely from the United States. Standard methods of cleaning and disinfection appear adequate to prevent transmission of HCV via contaminated endoscopes.[182] Additional studies to assess the mechanisms of HCV transmission in hemodialysis centers are needed. In addition, strategies to prevent transmission in hemodialysis centers need to be validated.

HCV acquisition via percutaneous injury is an important hazard for medical personnel. The lack of proven effective pre- or postexposure prophylaxis, the current prevalence of chronic HCV infection in the general (approximately 2%) and patient populations, and the rate of seroconversion following percutaneous injuries (1.8%) mean that HCV infection represents the most important bloodborne-transmitted disease threat to healthcare personnel. Efforts at prevention of HCV transmission to healthcare workers should focus on general measures to reduce the incidence of needlestick injuries.

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