Preventing the spread of hepatitis B and C viruses: Where are germicides relevant?

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Hepatitis B virus (HBV) and hepatitis C virus (HCV) are the most prevalent bloodborne pathogens. Infections caused by these organisms can become chronic and may lead to liver cirrhosis and carcinoma. Limited chemotherapy is now available, but only HBV can be prevented through vaccination. Both viruses are enveloped and relatively sensitive to many physical and chemical agents; their ability to survive in the environment may not be as high as often believed. As a result, their spread occurs mainly through direct parenteral or percutaneous exposure to tainted body fluids and tissues. Careful screening of and avoiding contact with such materials remain the most effective means of protection. Nevertheless, the indirect spread of these viruses, although much less common, can occur when objects that are freshly contaminated with tainted blood enter the body or contact damaged skin. Germicidal chemicals are important in the prevention of HBV and HCV spread through shared injection devices, sharps used in personal services (such as tattooing and body piercing), and heat-sensitive medical/dental devices (such as flexible endoscopes) and in the cleanup of blood spills. Microbicides in vaginal gels may also interrupt their transmission. General-purpose environmental disinfection is unlikely to play a significant role in the prevention of the transmission of these viruses. Testing of low-level disinfectants and label claims for such products against HBV and HCV should be discouraged. Both viruses remain difficult to work with in the laboratory, but closely related animal viruses (such as the duck HBV) and the bovine viral diarrhea virus show considerable promise as surrogates for HBV and HCV, respectively. Although progress in the culturing of HBV and HCV is still underway, critical issues on virus survival and inactivation should be addressed with the use of these surrogates. (Am J Infect Control 2001;29:187-97)

Viral hepatitis, caused by several unrelated viruses, is a significant problem of human health globally. Currently, we know of hepatitis A, B, C, D, E, and G viruses as the cause of this disease in humans. Hepatitis A virus and hepatitis E virus are enteric pathogens that spread primarily by the ingestion of fecally contaminated food or water.[1,2] The viremic stage of hepatitis A is relatively short, and chronic carriage of virus does not occur.[3] Thus, its bloodborne spread is infrequent. Viruses that are closely related to hepatitis E virus cause viremia in their respective animal hosts.[4] Although this may be true in humans as well, the extent of hepatitis E virus that is spread through blood remains unknown. Hepatitis D virus is a satellite of hepatitis B virus (HBV) and, as a

result, cannot infect hosts on its own. Not much is known about hepatitis G virus,[5] except that it can spread through tainted blood and that it is similar to hepatitis C virus (HCV). TT virus is a relatively recent discovery,[6,7] and we know even less about its relative importance to hepatitis in humans.

HOW IMPORTANT ARE HBV AND HCV?

HBV and HCV, on the other hand, are the most prevalent bloodborne pathogens.[8-10] Hepatitis caused by these viruses can also be quite severe and debilitating; their potential to induce a chronic carrier state, even liver cirrhosis and cancer,[11,12] further enhances their health impact. The overall hepatitis rate in the world varies from less than 1% in industrialized countries to 20% in certain regions of Southeast Asia; there are more than 350 million chronic HBV carriers worldwide,[13] and the corresponding figure for HCV is approximately 170 million chronic carriers.[14]

The number of chronic HBV carriers in the United States may be as high as 1.4 million[14]; in Canada, the number of chronic carriers may be at least 100,000.[15] There are nearly 4 million cases of chronic HCV in the United States, which result in at least 10,000 fatalities caused by liver disease every year.[16] The economic losses from health care costs and lost work because of HCV

in the United States are estimated to be $600 million per year.[16] The number of HCV cases in Canada may be high as 270,000.[17]

There has been limited success in the chemotherapy of HBV and HCV.[18,19] Vaccines against HCV are not yet available; sustained, long-term vaccination campaigns are needed for a substantial reduction in the health impact of HBV.

HBV, which belongs in the genus *Hepadnavirus* in family Hepadnaviridae, is an enveloped virus with a particle diameter of 42 to 45 nm.[18] Its genome consists of a double-stranded, linear DNA.[20] HCV, recently placed in genus *Hepacivirus* of the family Flavivi-ridae, consists of a 40 to 50-nm–diameter enveloped particle with a single-stranded, positive-sense RNA.

Both viruses are difficult to culture in the laboratory, which seriously limits our understanding of their environmental survival and the studies on the need for and choice of chemical germicides in the prevention/control of their environmental transmission. The following critical look at what is already known should help in designing logical and realistic approaches to infection control and in identifying areas for further investigation. Previously, we have presented similar reviews on HIV.[21,22] For a more general background on the virucidal activity of germicides, the reader is referred to earlier publications.[23]

The human health significance of both HBV and HCV is undeniable. We also know much about the means of their spread in nature. Questions persist, however, about the ability of HBV and HCV to survive in the environment and the potential for their spread through environmental surfaces and fomites. There is also much debate on the relevance of chemical germicides in interrupting such spread. All this impacts directly on the routine practices of infection control. This review will therefore critically assess the available information, in an effort to provide the reader with a better perspective about the stability and germicide resistance of the 2 viruses.

HOW DO HBV AND HCV SPREAD IN NATURE?

The horizontal spread of HBV and HCV occurs almost exclusively when virus-containing material is directly injected or is deposited on mucous membranes or damaged skin. The number of infectious HBV and HCV particles in the blood of infected individuals can be as high as 10^9/mL and 10^6/mL,[24] respectively. These viruses are also present in saliva and semen and, at least in the case of HBV, injection or ingestion[25,26] of saliva; the injection[27] or intravaginal instillation of semen into subhuman primates[28] can lead to infection. Feces, nasal discharge, and urine do not spread HBV and HCV, unless they are contaminated with blood.[29] In

fact, HBV is rapidly inactivated by enzymatic activity in feces and sewage.[30] The median infective dose of these viruses for humans is not known.

Transfusion of tainted blood and blood products, needlestick injuries,[31] surgical procedures,[32,33] and improperly decontaminated medical devices[34-39] are the main means of nosocomial and iatrogenic spread of the 2 viruses.

In the general community, HBV and HCV transmission occurs mainly from the sharing of drug injection/inhalation devices and intimate person-to-person contact.[16,40,41] Tattooing,[42] ear and body piercing, acupuncture,[43] electrolysis for hair removal,[20,44] and the sharing of shaving-razors,[45] toothbrushes,[20] and bathbrushes[46] have also been implicated.

In 10% to 40% of HBV and HCV cases, the means of virus spread remain unidentified.[47] The fact that there are no seasonal patterns to the spread of these viruses strongly suggests parenteral or percutaneous exposure that is not apparent. Despite suggestions to the contrary,[48] there is also no evidence for the airborne transmission of these viruses.[49] Gibbons did not become infected when HBV-positive saliva was sprayed into their mouths or noses.[26]

The true role of hands in HBV and HCV spread remains difficult to determine. However, there are several anecdotal reports of nosocomial HBV spread by the hands of infected health care personnel.[20] We are not aware of any studies in which environmental surfaces have been clearly incriminated in the spread of HBV and HCV. Blood-contaminated computer data cards are believed to have transmitted HBV in the clinical laboratory of a hospital,[50] but chemical germicides would have been of little relevance in the control or prevention of such spread.

HOW WELL DO HBV AND HCV SURVIVE IN THE ENVIRONMENT?

Virtually nothing is known about the ability of these 2 viruses to survive on animate surfaces such as human skin. The influence of various environmental factors on the infectivity of the 2 viruses has also not been studied properly; the information often quoted about the environmental stability of HBV and HCV comes from experiments in which the integrity of viral particles,[51] antigens,[52,53] nucleic acid,[54,55] or enzymes[56] were used as indicators for the presence or absence of infectious virus. Doubtless, such approaches were justified in the absence of readily available means of detecting and quantitating infectious virus particles, but one must interpret their conclusions very carefully. For example, when medical devices that were disinfected with 2% alkaline glutaraldehyde were tested for the presence of the duck HBV (DHBV), polymerase chain reaction showed many

Table 1. Summary of the findings from selected studies on germicide inactivation of HBV with the chimpanzee model

Germicide tested	Test conditions	Degree of virus inactivation	Citation number
0.7% (w/v) Formaldehyde	1 Hr at 20°C (68°F)	99.9%	66
Bleach (500 ppm free chlorine)	10 Min at 20°C (68°F)	Complete inactivation	64
2% (w/v) Glutaraldehyde	10 Min at 20°C (68°F)	Complete inactivation	64
70% Isopropanol	10 Min at 20°C (68°F)	Complete inactivation	64
1% Glutaraldehyde	5 Min at 24°C (75.2°F)	Complete inactivation	65
0.1% Glutaraldehyde	5 Min at 24°C (75.2°F)	Complete inactivation	65
80% (v/v) Ethanol	2 Min at 11°C (51.8°F)	Complete inactivation	65
Quaternary ammoniums (500 and 703 ppm)	10 Min at 20°C (68°F)	Complete inactivation	61
Phenolic (702 ppm)	10 Min at 20°C (68°F)	Complete inactivation	61

of them to be positive, although no infectious virus could be detected when the same samples were injected into susceptible ducklings.[57]

In particular, does HBV survive on contaminated objects and surfaces better than would be expected of enveloped human pathogenic viruses in general? If so, is its enhanced survival because of greater protection afforded by blood? Or, are the median infective dose of the virus so low and the titer of the virus in blood so high that blood-contaminated materials remain a potential biohazard in spite of a relatively rapid decline in the titer of viable virus? Understandably, clear answers to these questions are not available because of the difficulties (mentioned earlier) in working with these viruses. However, now that safe and suitable surrogates and animal models are available, attempts must be made to address these issues so that more rational approaches to infection control could be formulated.

Virtually nothing is known about the environmental survival of HCV, except that its RNA in plasma or serum was found to be stable at 4°C for 7 days.[58] However, the stability of viral RNA should not be equated with the preservation of virus infectivity.

HOW RESISTANT ARE HBV AND HCV TO CHEMICAL GERMICIDES?

Relatively little is known about the inactivation of HBV and HCV by chemical germicides, and the wide variations used in working with these viruses in particular make it quite difficult to properly compare the limited data that are available. The well-recognized flaws in commonly used methods for testing virucidal activity in general also compromise the quality of the available information.[59] For example, the time of contact between the virus and the test product is often much too long to be realistic for field use, and the "soil load" in the test virus suspension may not be reflective of difficult-to-deal-with body fluids, such as blood.

HBV is not as resistant to germicides as was once believed,[60,61] and very limited testing in the past few years suggests that even relatively weak virucidal

chemicals (such as quaternary ammonium compounds) can inactivate it.[61,62] This applies to HCV as well. The obvious limitation to a more thorough evaluation of germicides against these viruses is the inability to culture them in vitro; to date, no standards-setting organization anywhere in the world has established any methods or guidelines for the testing of chemical germicides against HBV and HCV. This should now be addressed with the use of appropriate surrogates.

HOW ARE GERMICIDES TESTED AGAINST HBV AND HCV?

Chemicals are regularly used in rendering biologicals (such as blood products free of HBV, HCV, and other infectious agents),[63] but this review will focus only on those germicides that are commonly used for infection control in institutional and community settings.

Testing against HBV

Testing with chimpanzees. The initial tests on the stability of HBV and its susceptibility to chemical germicides used chimpanzees as experimental animals.[51] Such susceptibility studies, even though often based on the less challenging suspension test, used HBV-containing serum or plasma from naturally infected subjects and clearly demonstrated that the virus was relatively easy to inactivate.[64,65] Subsequent studies confirmed this.[51,61] Table 1 summarizes the findings of representative studies that were based on the chimpanzee model and HBV inactivation by chemical germicides.

Chimpanzees are an endangered species. Therefore, their use in testing germicides against HBV, or any other pathogen, is neither desirable nor feasible for routine use. Although they are still used in certain types of research and testing, work with them requires considerable expense and specialized facilities. Moreover, the number of chimpanzees at any given facility in North America is generally too small to allow sufficient numbers of test and control animals for a proper germicide test. Where they have been used for such testing, the statistical power of the data that were generated has been

seriously compromised because the entire test was conducted with a very small number of animals.[61]

The morphologic alteration and disintegration test (MADT). Thraenhart et al[66] introduced the MADT in 1978. The technique was subsequently standardized against the chimpanzee model, and this was adopted as a means to determine virucidal activity of chemicals. Briefly, after subjecting HBV particles to the test formulation, they are isolated with sucrose gradient sedimentation and viewed by electron microscopy, and a ratio of altered and disintegrated particles to native particles is calculated. Based on this ratio, the HBV-inactivating activity can be determined. Although crude and rudimentary, this technique has allowed numerous disinfectants to achieve a claim against HBV.[67]

Even though MADT uses the human HBV itself, the test procedure is too cumbersome to be suitable for routine use. It also has several other limitations. It relies on very expensive equipment and personnel with considerable experience and skill in electron microscopy. It needs HBV suspensions, which are not only highly concentrated but also pure enough to allow the viral particles to be readily visualized and counted under the electron microscope. Furthermore, because chemical germicides (such as glutaraldehyde and alcohol) act by fixing proteins and preserving the structural integrity of the material being treated, virus particles exposed to them may appear morphologically unaltered although being noninfectious; this could lead to false-negative results. Work with concentrated suspensions of HBV can be biohazardous.

Testing based on HBV polymerase inactivation. The testing of germicides based on the inactivation of the activity of HBV polymerase has also been attempted.[56] Such testing has not met with wide acceptance because it is not only based on an indirect measure of virus infectivity but also requires highly purified virus preparations. The sensitivity of the test is also questionable.

Testing with animal hepatitis viruses as surrogates. More recent developments in the testing of chemical germicides against HBV have focused on the use of 3 different animal species and the viruses that cause hepatitis in them: the woodchuck,[68] the ground squirrel,[69] and the Pekin duck.[57,62,70-73] Whereas all 3 viruses are similar to human HBV, the duck virus resembles it more closely in viremia, carcinoma production,[74] and inactivation profiles.[75,76] The DHBV can also infect primary duck liver cells in vitro, thus making the test more cost-effective compared with the use of chimpanzees or even ducklings as experimental animals.[62,77] DHBV is also much safer to work with than HBV.

The US Environmental Protection Agency, issued guidelines in August 2000 on protocols for testing the efficacy of disinfectants that use DHBV as a surrogate for HBV. In 1 such method MicroBioTest, Inc (Sterling, Va),[62,77] carriers inoculated with DHBV are dried and then exposed to the test formulation. After a specified contact time, the disinfectant-virus mixture is eluted off the test carriers, neutralized, and then serially diluted for culture in duck hepatocytes. Detection of DHBV replication is performed either by immunofluorescence or by nucleic acid detection methods. This protocol also complies with other methods for testing virucides.[79,80]

We are aware of only 1 other commercial laboratory that currently has the capability to test chemical germicides against DHBV with either ducklings or duck hepatocytes.

More recently, Deml et al[81] have stably transfected the HBsAg into Drosophila Schneider-2 cells. The mass production of the antigen may lead to higher protein loads for disinfectant testing and for further understanding of the antigen's properties and stability. This relatively inexpensive approach may allow for the rapid screening of germicides for their ability to denature HBsAg as an indicator of their potential to inactivate HBV itself.

Testing against HCV

Until recently, there were no in vitro tests for the virucidal activity of chemical germicides against HCV. The bovine viral diarrhea virus (BVDV) has some properties similar to HCV[82] and has been used in the blood product industry as a surrogate for HCV.[83,84,85]

HCV has been found to replicate in Vero cells without producing any cytopathic effects.[86] Because molecular or immunologic methods can be used to detect the virus in infected cells, this opens the door for testing of germicides against it directly.[87]

As would be expected, the enveloped nature of HCV makes it relatively susceptible to inactivation by phenolics and a chlorine-based compound.[87]

HOW GOOD ARE COMMONLY USED GERMICIDES AGAINST HBV AND HCV?

The following specific details elucidate the known or expected activities of major classes of chemical germicides against these 2 viruses and the application of such chemicals in health care. The same information is relevant to other settings in which there is potential for HBV and HCV to be spread by means other than direct person-to-person contact and transfusion of tainted blood products.

Aldehydes

As can be seen from Table 1, formulations that are based on formaldehyde and glutaraldehyde can be highly

Table 2. Various means by which HBV and HCV are spread and the relevance of chemical germicides in infection control

Means of spread	Degree of relevance	Comments concerning germicides
Spread from infected mother to fetus during childbirth and/or breast-feeding; artificial insemination (unscreened donors); organ transplantation (unscreened donors); accidental needles and sharps exposure; contact with blood in sports (eg, wrestling)	Very low	Germicides have no role in the prevention of such spread.
Transfusion of improperly screened blood or blood products	High	Germicides, alone or in combination with physical agents, can be used for virus inactivation in blood products.
Sharing of needles and syringes in illicit drug use; sharing of paraphernalia in the use of noninjectable drugs; use of contaminated needles and syringes in the administration of injectables; use of improperly decontaminated medical, dental, and surgical devices; use of blood-containing sharps and instruments in ritual scarification, circumcision, blood-letting, tattooing, ear- and body-piercing, acupuncture, hair removal by electrolysis, and sharing of shaving razors	Very high	Can play a crucial role in interrupting virus spread through such means. This is especially true in the decontamination of shared needles and syringes; although bleach is commonly recommended and used for this purpose, there is an urgent need to find an equally cheap, effective, yet safe substitute for it. Such objects may pose the greatest risk when freshly contaminated; items such as toothbrushes are not meant to be shared and are also generally unsuitable for chemical disinfection; but, if items such as disposable or nondisposable shaving razors are to be shared, they must be chemically disinfected between different users.
Hemodialysis with shared equipment and in inadequately cleaned and monitored settings	Moderate	Chemical disinfection of shared hemodialysis equipment can reduce the risk of virus spread. The use of gloves and other standard precautions would be more useful than the use of chemical germicides alone for the decontamination of environmental surfaces.
Unprotected sexual contact with virus-infected individuals	Moderate	In addition to barrier protection, use of germicidal gels may reduce the risk of such spread; however, chemicals that can inactivate the viruses may not be safe for repeated long-term use.
Nonvenereal contact in domestic and institutional settings with chronic carriers of HBV or HCV	Low	The vehicle(s) for such spread, which occurs predominantly in conditions of overcrowding and poor hygiene, remain(s) unidentified. The sharing of toys and items of personal use such as toothbrushes are most likely to play a role; in which case, the use of germicides is unlikely to be useful in infection control.
Nosocomial and iatrogenic spread other than through the use of contaminated medical, dental, and surgical devices	Low to moderate	In most settings, hands probably play a minor role in the spread of the viruses; however, regular and proper hand washing with soap and water may be sufficient to virtually eliminate the risk. Use of alcohol-based hand gels between handwashings is also considered effective; residual germicidal activity is not likely to be protective if damaged skin of hands is exposed blood containing HBV or HCV. Any HBV or HCV on the skin surface would be readily removed/inactivated during the scrubbing procedure; however, the viruses in any leaked blood during surgical procedures from the chronically infected hands of a surgeon would most likely remain infectious. Skin antisepsis may be helpful only in situations in which the surgical site is contaminated with blood other than that of the patient.
Contact with environmental surfaces	Low to moderate	Environmental surfaces rarely act as vehicles for the 2 viruses, with the possible exception of those viruses in hemodialysis units. Germicide decontamination of spills of blood and other contaminated fluids before and after their clean up forms an essential part of infection control.
Nonintact or compromised skin (eg, chapped hands)	Moderate	Topical agents may play a role, but proper testing is needed to confirm product potency.

effective in inactivating HBV and HCV.[51,54,57] We are not aware of any published data on the activity of orthophthaldehyde against these 2 viruses, but it can be safely assumed that it too can inactivate them readily.

Recent and well-designed studies with DHBV have clearly reinforced the importance of precleaning in the chemical disinfection of heat-sensitive medical devices. One such study[57] has clearly demonstrated that decontamination, even with otherwise highly effective chemicals such as glutaraldehyde, can fail in the absence of proper cleaning of the devices that are being disinfected.

It is interesting to note that, approximately 2 decades ago, glutaraldehyde-based products were being recommended as a substitute for bleach in the decontamination of environmental surfaces.[88] Obviously, this view is no longer relevant in view of the current safety concerns with glutaraldehyde. However, such use continues in some places.

Chlorine and iodine

Sehulster et al[53] showed that exposure of Dane particles of HBV to sodium hypochlorite (5600 ppm) disrupted them and also inactivated their polymerase activity. Agolini et al[87] have shown chlorine (2500 ppm) could reduce the binding of HCV to host cells and that a contact time of at least 10 minutes was required to achieve a 91.7% reduction in cell binding and infection. This observation needs confirmation.

No differences were found in the susceptibility of HBV and DHBV to approximately 3000 ppm of available chlorine as bleach or as sodium dichloroisocyanurate, a compound that releases chlorine on demand.[72]

A 1:10 dilution of domestic bleach, which contains about 5000 ppm of available chlorine, is commonly recommended for the clean up of blood spills, and this level of chlorine should be considered more than adequate to deal with HBV and HCV in such blood.[44] However, the use of undiluted bleach (>50,000 ppm of available chlorine) for the decontamination of shared needles and syringes[89] requires review.

Experimental data on the ability of iodine-based germicides to inactivate HBV and HCV are limited, but it is expected that such products would be effective in concentrations equivalent to those of available chlorine.

Phenolics and quaternary ammonium compounds

Prince et al[61] determined the activity of 2 quaternary ammonium-based products (500 and 700 ppm) and a phenolic (700 ppm) with a carrier test with either human HBV or DHBV. The contact time was 10 minutes at 20°C; all products proved effective against both viruses in the chimpanzee inoculation and MADT tests.

Agolini et al[87] have also determined that subjecting HCV to a phenolic for 5 minutes effectively eliminated the ability of the virus to attach to Vero cells.

Alcohols

Ethanol and isopropanol, in the range of 70% to 80%, are effective against HBV[64,65] and most likely against HCV as well. Therefore, alcohol-based surface disinfectants, hand rubs, and preoperative skin preparations would be expected to interrupt virus spread effectively. However, it is important to ensure adequate contact between the disinfectant and the viruses on contaminated surfaces. This may not always occur by simple wiping with alcohol. Furthermore, the presence of gross amounts of blood may interfere with the germicidal action of alcohols because of their fixative properties that may hinder the ability of alcohols to penetrate through the dried organic debris.

Peroxygen systems and gas plasma

Vickery et al[90] have shown that the Sterrad system, which is based on a high concentration of vaporized hydrogen peroxide, was highly effective in inactivating DHBV, even in the presence of blood as a soil load. Formulations that are based on stabilized hydrogen peroxide[91] have not been tested against HBV but would be expected to work against it on the basis of their activity against tougher organisms, such as mycobacteria and nonenveloped viruses.[91,92]

Smith and Pepose[39] regard 3% hydrogen peroxide to be adequate for the inactivation of a variety of pathogens, including HCV, on tonometer prisms and trial contact lenses. It is important to note that a 3% solution of hydrogen peroxide, unless mixed with other chemicals to accelerate and potentiate its activity, is a relatively weak germicide[93] and may require several hours of contact to be effective against susceptible organisms such as vegetative bacteria and enveloped viruses.

We are not aware of any published data about the activity of the Steris system against HBV and HCV, but it is most likely to be effective against them because of the relatively high levels of peracetic acid and temperature used.

Gasparini et al[94] showed that a 1% (weight/volume) solution of Virkon (Antec International, Suffolk, UK) could destroy the surface antigen of HBV (HBsAg) with a contact time of 10 minutes. The virus challenge was a 1:30 dilution of a pool of HBsAg-positive sera. The authors suggest that the low toxicity and nonirritating nature of this product also make it a better substitute for glutaraldehyde. Similar studies have been performed with the no-foam version of Virkon, and a 3% solution of the product was found to be effective against HBV in a contact time of 10 minutes.[95]

Sodium hydroxide

As would be expected, 0.1 mol/L NaOH was found capable of inactivating pseudorabies virus and BVDV,

which are used as surrogates for HBV and HCV, respectively, in 30 seconds at 60°C.[84] Obviously, the highly corrosive nature of this procedure restricts its use to the treatment of biomedical wastes and process residues.

Acidic electrolyte water

A recent study that used acidic electrolyte water has shown that a 5-minute exposure resulted in complete loss of HCV infectivity.[55] These observations, based on the detection of viral RNA as an indicator for the presence of absence of infectious virus, require corroboration. However, these electronically produced mixed oxidant systems may be effective at lower concentrations than single oxidant species such as chlorine.

Other types of germicidal chemicals, including topicals

The relatively low resistance of HBV and HCV to germicides that have been tested thus far indicates strongly that many properly formulated products, based on a variety of chemicals, may also inactivate the 2 viruses. This may include some novel formulations, and the advent of acceptable surrogate test systems promises to expand our understanding of HBV and HCV disinfection.

Special mention must be made for topical products. Widespread use of products such as chlorhexidine gluconate in infection control suggests that they should be examined for activity against HBV and HCV. Many other active ingredients in topicals fall under 1 or more of the chemical classes already mentioned. The concentrations of such chemicals in topicals, however, are often lower than in surface or medical device disinfectants. Use of surrogates to test a carefully selected range of such products would be a useful addition to our knowledge. Given the high risk of conducting such testing on human subjects, the use of suitable ex vivo skin models should also be considered for this purpose.[96]

WHERE ARE GERMICIDES MOST RELEVANT IN INTERRUPTING THE SPREAD OF HBV AND HCV?

Table 2 summarizes the recognized means of HBV and HCV spread and the relative importance of chemical germicides in interrupting their transmission.

Decontamination of shared needles and syringes

There is no doubt that injecting drug users are at the greatest risk of acquiring a bloodborne infection because of the practice of sharing needles,[97] and it is estimated that 50% to 94% of injecting drug users in the United States are infected with HCV.[98] In developing countries, needles and syringes are frequently reused, without proper decontamination between patients, for the injections of medications. Nearly one half of more

than 10 billion such procedures are believed to be unsafe and to expose millions to HBV and HCV.[97]

At the moment, there is only 1 rapid and cost-effective method to interrupt the spread of bloodborne pathogens through shared needles and that is the proper use of a germicide to disinfect the needles between uses. Domestic bleach is often recommended and used for this purpose.[89]

It must be remembered here that illicit-drug users often also share other paraphernalia related to drug use, and emphasis on the decontamination of shared needles alone may not be sufficient to eliminate the problem. Furthermore, individuals with nasal ulcers run the risk of acquiring these infections when they share drugs that are sniffed, and such spread remains difficult to prevent.

Disinfection of critical and semicritical heat-sensitive medical devices

Improperly decontaminated medical devices can play a role in the spread of bloodborne pathogens; HBV and HCV are no exception in this regard. At the same time, it must be remembered that high-level disinfectants as a class should be considered strong enough to inactivate these 2 viruses on such instruments with proper cleaning before use.[73]

The duck hepatitis model offers considerable promise in the evaluation of emerging products and technologies for the decontamination of HBV-contaminated medical devices. Parallel studies on HCV may not be necessary in view of the fact that it is not known to be any more resistant than HBV.

Spermicidal gels

Chemicals such as nonoxynol-9, commonly used in spermicidal gels, or invisible condoms, can produce microulceration of the vaginal mucosa with prolonged use, thereby actually increasing the risk of exposure to pathogens such as HIV, HBV, and HCV.[99] Renewed efforts are needed to find safer substitutes for such chemicals and properly test their activity against major types of sexually transmitted pathogens.

CONCLUDING REMARKS AND RECOMMENDATIONS

Our knowledge, which is based on the environmental survival of HBV and HCV, remains very limited because of the obvious difficulties in working with these viruses in the laboratory. The information that is available requires careful interpretation because of the recognized limitations of the methods used to generate it. Although experimentation with the 2 viruses still remains somewhat difficult, there is a strong need to apply the use of surrogates in reevaluating the poten-

tial of such viruses to survive in the environment. The DHBV and BVDV models show considerable promise in this regard.

Fortunately, the spread of HBV and HCV in the general public remains quite low in industrialized regions. However, those who are at high risk through activities such as injecting drug use, high-risk sexual practices, and tattooing must be made aware of the higher potential for exposure to these viruses. Increasing levels of vaccination against HBV will obviously reduce the prevalence of HBV, but as of yet, there is no such preventative measure available for HCV.

Even in industrialized countries, many segments of the general public are still woefully ignorant or misinformed about the modes and vehicles of disease spread and the basics of infection control.[100] This applies to even highly publicized diseases such as AIDS. Infection control practitioners also need to be informed better about the need for and selection of germicides in dealing with HBV and HCV. Although many of the studies cited here show successful inactivation of HBV and HCV, it must be emphasized that the test conditions often bear little resemblance to field use. The proposed surrogates offer the opportunity to examine HBV and HCV disinfection under more realistic conditions. This is particularly true for HBV using the DHBV model as already shown by Chaufour et al.[73] In our view, environmental surface disinfectants to be used in most settings require no demonstrated activity or label claims against such viruses.

Manufacturers of chemical germicides must be actively discouraged from having their products tested against HBV and HCV with the use of animals such as the chimpanzee. Label claims against such viruses may be permitted for high-level disinfectants only when the testing has been conducted with (1) a proper carrier test, (2) a suitable surrogate virus, (3) a soil load high enough to reflect that found in blood and other body fluids, (4) a contact time and product:target virus ratios commensurate with the recommended field use(s) of the product, and (5) the use of sufficient replicates from at least 3 lots of the product. The importance of proper product neutralization and other controls to make the results scientifically and statistically valid also needs to be emphasized. In the case of cell culture, it is important to show that any product residual affects neither the virus nor the virus-cell interactions, which form the basis for the assay.[23]

Massive education campaigns should be mounted to reduce needle sharing and/or the proper decontamination of devices used for injecting illicit drugs. The reuse of disposable syringes and needles by health care personnel is a serious problem in developing countries.[101] There is an urgent need to encourage the use of single-use or sterilizable injection devices.[102] When the use of disposable devices cannot be avoided, those using them must be educated and trained in proper decontamination of such items between uses.

The recently published guidelines for those individuals who provide personal services such as tattooing, ear/body piercing, and electrolysis[44] are a very welcome development. However, for these guidelines to make the desired impact, it will be crucial to publicize them as widely as possible and to encourage relevant trade and professional organizations to hold regular information/training sessions for those individuals who provide such services.

The widest possible coverage of HBV vaccination of health care personnel and others at risk is needed. Such vaccination programs, together with blood-screening and other prevention and control measures, could very well see the eradication of this disease and the elimination of the hepatocellular carcinoma associated with it.

In view of the difficulties of the in vitro culture of HCV and the possible existence of several immunologically distinct types, sufficient resources must be made available to encourage sustained and substantial efforts to develop a safe and effective vaccine against HCV.

The modes and vehicles for the spread of HBV and HCV often remain unknown, possibly because of incomplete reporting or inapparent exposure to the viruses. Refinements in data gathering are necessary to reduce the numbers of cases in which virus exposure remains undetermined.

Glutaraldehyde and ethylene oxide, both commonly used for decontaminating heat-sensitive medical devices, are unsafe for humans. Accidental or deliberate exposure of eyes to domestic bleach, a germicide frequently used in the decontamination of shared disposable needles and syringes, can be quite harmful and has recently caused concerns for the safety of penitentiary staff in particular. Therefore, better and safer substitutes for these chemicals are urgently needed.

Manufacturers of reusable and disposal medical devices must be encouraged to work with germicide makers and infection control practitioners and other health care workers so that such devices can be made safer and easier to clean and disinfect. Lack of such input increases the risk of the spread of infections. For example, a spring-loaded fingerstick device for blood sample collection, designed to hold a sterile and disposable lancet, was incriminated in the spread of HBV because the reusable holder itself would become contaminated with blood but was not required to be decontaminated between uses.[103]

The continuing reports of HBV and HCV spread in hemodialysis units, even those that apparently adhere strictly to established infection control guidelines,[104]

require further investigation to elucidate the exact means of virus spread. Such studies should also help in better defining the need for environmental decontamination in such settings.

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