

The effectiveness of hand hygiene procedures in reducing the risks of infections in home and community settings including handwashing and alcohol-based hand sanitizers

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Infectious diseases (ID) circulating in the home and community remain a significant concern. Several demographic, environmental, and health care trends, as reviewed in this report, are combining to make it likely that the threat of ID will increase in coming years. Two factors are largely responsible for this trend: first, the constantly changing nature and range of pathogens to which we are exposed and, secondly, the demographic changes occurring in the community, which affect our resistance to infection. This report reviews the evidence base related to the impact of hand hygiene in reducing transmission of ID in the home and community. The report focuses on developed countries, most particularly North America and Europe. It also evaluates the use of alcohol-based hygiene procedures as an alternative to, or in conjunction with, handwashing. The report compiles data from intervention studies and considers it alongside risk modeling approaches (both qualitative and quantitative) based on microbiologic data. The main conclusions are as follows: (1) Hand hygiene is a key component of good hygiene practice in the home and community and can produce significant benefits in terms of reducing the incidence of infection, most particularly gastrointestinal infections but also respiratory tract and skin infections. (2) Decontamination of hands can be carried out either by handwashing with soap or by use of waterless hand sanitizers, which reduce contamination on hands by removal or by killing the organisms in situ. The health impact of hand hygiene within a given community can be increased by using products and procedures, either alone or in sequence, that maximize the log reduction of both bacteria and viruses on hands. (3) The impact of hand hygiene in reducing ID risks could be increased by convincing people to apply hand hygiene procedures correctly (eg, wash their hands correctly) and at the correct time. (4) To optimize health benefits, promotion of hand hygiene should be accompanied by hygiene education and should also involve promotion of other aspects of hygiene. (*Am J Infect Control* 2007;35:S27-64.)

There can be no doubt that advances in hygiene during the 19th and 20th centuries, along with other aspects of modern medicine, have combined to

improve both the length and quality of our lives. However, since the middle of the 20th century, following the development of vaccines and antimicrobial therapy,

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This document has been developed as a special project by the International Scientific Forum on Home Hygiene (IFH; www.ifh-homehygiene.org). IFH is a nongovernmental, not for profit organization that is working to raise awareness of the importance of hygiene in the home and to develop and promote a strategy for home hygiene based on sound scientific principles. The first draft of this document was prepared by Professor Sally Bloomfield and Dr. Allison Aiello. An expert group convened by IFH,

comprising Professor Bloomfield, Dr. Aiello, Professor Elaine Larson, Professor Barry Cookson, Dr. Michele Pearson, and Dr. Carol O'Boyle met at Columbia University, New York, on March 22, 2007, to review, discuss, and develop the review and agree on final content. The information contained in this document is based on the database of scientific literature on home hygiene that has been accumulated by the IFH over the past 10 years, together with contributions from the knowledge base of all the authors. A PubMed search covering 2002 to 2007 was carried out using the terms "hygiene," "home," "handwashing," and "alcohol" to ensure that recent literature was not overlooked. The section on intervention studies was based on a systematic review of the relevant literature.

Supported by McNEIL-PPC, Inc., through an unrestricted educational grant.

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0196-6553/\$32.00

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doi:10.1016/j.ajic.2007.07.001

and with serious epidemics of the “old” infectious enemies such as diphtheria, tuberculosis, and others apparently under control, hygiene has tended to lose its prominent position, and the focus of concern has shifted to degenerative and other chronic diseases. Nowhere has the decline in concern about hygiene been more evident than in the home and community.

However, whereas advances in medicine and public health seemed, at one time, to offer the possibility that infectious diseases (ID) might soon be a thing of the past, it is now clear that this is not the case. In the past 20 years, concern about ID and the need for prevention through home and community hygiene has moved steadily back up the health agenda. Between 1980 and 1992, deaths attributable to ID increased by 22% in the United States alone, representing the third leading cause of death among US residents.¹ Two factors are largely responsible for this trend: first, the constantly changing nature and range of pathogens to which we are exposed and, secondly, the changes occurring in the community, which affect our resistance to infection. To what extent our more relaxed attitudes to hygiene practice have contributed to these trends is not known, but poor hygiene is a significant factor for a large proportion of the gastrointestinal (GI), skin, and respiratory tract (RT) infections, which make up the greatest part of the ID burden.

Prior to approximately 1980, common pathogens such as rotavirus, campylobacter, *Legionella*, *Escherichia coli* (*E coli*) O157, and norovirus were largely unheard of. Whereas methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* (*C difficile*) were once considered largely hospital-related problems, this is no longer the case. Now, community-associated MRSA (CA-MRSA) strains are a major public health concern in North America and, increasingly, in Europe. Most recently, the severe acute respiratory syndrome (SARS) outbreak and concerns about avian flu have raised awareness of the potential for transmission of respiratory viruses via hands and surfaces. Demographic trends mean that the proportion of the population in the community who are more vulnerable to infection is increasing, whereas trends toward shorter hospital stays and care in the community also demand increased emphasis on care of “at-risk” groups in the home who require protection from infection.

In assessing the potential for reducing ID transmission through hygiene practice, it is recognized that contaminated hands and failure to practice hand hygiene are primary contributors. In this report, we review the evidence base related to the impact of hand hygiene in reducing transmission of ID in the home and community. This report focuses on developed countries, most particularly North America and Europe, within the context of renewed public health concerns about IDs and

their impact on health and well-being. The review also evaluates the use of alcohol-based hand hygiene procedures as an alternative to, or in conjunction with, hand-washing. These products are defined by a number of different terms in Europe and North America (hand sanitizers, handrubs, and others). For the purposes of this report, we will refer to them as alcohol-based hand sanitizers (ABHS). Although this report focuses primarily on the home, it is recognized that the home forms a continuum with public settings such as schools, offices, and public transport and cannot be considered totally in isolation. Nevertheless, the hand hygiene practice framework proposed in this review is largely also applicable to “out of home” settings.

This report compiles data from intervention studies and considers it alongside risk modeling approaches based on microbiologic data. Currently, there is a tendency to demand that, in formulating evidence-based policies and guidelines, data from intervention studies should take precedence over data from other approaches. Although there are those who still adhere to this, it is accepted increasingly that, as far as hygiene is concerned, because transmission of pathogens is highly complex and involves many different pathogens each with multiple routes of spread, decisions regarding infection control must be based on the totality of evidence including microbiologic and other data.

This document is intended for infection control and public health professionals who are involved in developing hygiene policies and promoting hygiene practice for home and community settings, including those involved with food and water hygiene, care of domestic animals, pediatric care, care of elderly adults, and care of those in the home who may be at increased risk for acquiring or transmitting infection. The purpose of the review is to provide support for those who work at the interface between theory and practice, particularly those involved in developing policies for the home and community, by providing a practical framework for hand hygiene practice together with a comprehensive review of the evidence base.

In recent years, a significant amount of research has been done to identify strategies for changing hygiene behavior. Whereas those who manage hygiene improvements often choose to promote hygiene by educating people on the links between hygiene and health, one of the lessons that has been learned is that traditional (cognitive) approaches can raise awareness but do not necessarily achieve the desired effects. If practices such as handwashing are to become a universal norm, a multidimensional promotion that engages the public is needed to persuade people to change their behavior. Although we recognize that this aspect is fundamental, it is outside the scope of this report and is reviewed elsewhere.²⁻⁶

THE BURDEN OF HYGIENE-RELATED DISEASES IN THE HOME AND COMMUNITY

Whereas, in the past, research and surveillance largely focused on health care-associated and foodborne illnesses, increasing resource is now being allocated to generating data that give a better view of the extent to which infections are circulating in the community; how they are being transmitted; and how this varies from one region, country, or community to another. Although the data in the following section represent a useful overview, we note that the data collection methods differed significantly from one study to another, which means that comparisons from different geographic locations must be interpreted with care. Current trends in communicable IDs in Europe are described in more detail in the recent (2007) European Communicable Disease Epidemiological Report from the European Centre for Disease Prevention and Control (ECDC).⁷

Infectious GI disease and hygiene

Foodborne disease. Rates of foodborne illness remain at unacceptably high levels, despite the efforts of food producers to ensure the safety of the food supply. Raw meat and poultry and fruits and vegetables bought at retail premises may be contaminated with pathogens. Good hygiene practices during food preparation in the home are therefore essential in preventing cross contamination of prepared foods from raw foods and preventing contamination of food by infected household members or domestic animals.

The European Food Standards Agency (EFSA) 2005 report⁸ and the 2007 ECDC report⁷ cite campylobacteriosis as the most reported animal infection transmitted to humans. In 2005, reported campylobacter infections increased by 7.8% compared with the previous year, rising to an incidence rate of 51.6 cases per 100,000 people. The EFSA states that the source of most human campylobacter infections is related to fresh poultry meat. On the other hand, Salmonella infections fell by 9.5% in 2005 to an incidence of 38.2 cases per 100,000 (176,395 reported cases). The 2003 World Health Organization (WHO) report⁹ concluded that approximately 40% of reported foodborne outbreaks in the WHO European Region over the past decade were caused by food consumed in private homes. The report cites several factors as "critical for a large proportion of foodborne diseases" including use of contaminated raw food ingredients, contact between raw and cooked foods, and poor personal hygiene by food handlers. United Kingdom data show that food poisoning notifications reached a peak in 1997-1998 and has since declined but remains in excess of 70,000 per year.¹⁰

In reality, the burden of food poisoning is much higher because most cases go unreported; according to the UK Food Standards Agency,¹¹ the true number of cases is approximately 4.7 million per year.

In 1999, Mead et al¹² reported on food-related illness in the United States, using data from a range of sources including national surveillance and community-based studies. They estimated that foodborne illness in the United States causes 76 million illnesses, 500,000 hospital admissions, and 9000 deaths each year. Most frequently recorded pathogens were campylobacter, Salmonella, and norovirus, which accounted for 14.2%, 9.7%, and 66.5%, respectively, of estimated foodborne illnesses. Data suggest that the total number of reported outbreaks has not declined substantially in recent years, ranging from 980 to 1400 outbreaks and between 20,000 and 80,000 cases per year for the years 2000 to 2005.¹³

Other infectious GI disease. From recent investigations, it is now recognized that a substantial proportion of the total infectious GI disease burden in the community is because of person-to-person spread within households, particularly for viral infections, where it is most often the cause. Person-to-person transmission in the home can occur by direct hand-to-mouth transfer, via food prepared in the home by an infected person, or by transmission because of aerosolized particles resulting from vomiting or fluid diarrhea. Apart from transmission by inhalation of airborne particles, these infections are preventable by good hygiene practice.

The 2003 WHO report⁹ stated that, of the total GI infection outbreaks (including foodborne disease) reported in Europe during 1999 and 2000, 60% and 69%, respectively, were due to person-to-person transmission. In the United Kingdom, it is estimated that up to 50% of GI infection results from person-to-person transmission.¹¹ A study of United Kingdom outbreaks¹⁴ suggested that 19% of Salmonella outbreaks and more than half of *E coli* O157 outbreaks are transmitted by nonfoodborne routes.

National surveillance systems vary in their methods of data collection but mostly focus on foodborne disease. Inevitably, this means that data on GI illnesses relate mainly to large foodborne outbreaks in restaurants, hospitals, and others, whereas sporadic non-foodborne cases in the general community go largely unreported. In the United Kingdom, even when "household" outbreaks are reported, they mostly involve home catering for parties and other functions and are therefore mainly foodborne outbreaks.¹⁵ Because milder cases of GI illness often go unreported, this means that the overall GI infection burden, particularly that which is not foodborne, is unknown; the most informative data on the overall burden of

Table 1. Estimated number of cases of infectious gastrointestinal disease in England and Wales associated with campylobacter, Salmonella, rotavirus, and norovirus

Organism	Number of laboratory reports from fecal isolates in 2005	Ratio of actual reported cases	Estimated number of cases in the community
Campylobacter	42,679	7.6	324,360
Salmonella	11,191	3.2	47,763
Rotavirus	13,306	35	567,790
Norovirus	2607	1562	4,072,734

infectious GI illness (both foodborne and non-foodborne) in the community come from various community-based studies, which have been carried out in Europe and the United States and are reviewed below.

Two large community studies have been carried out in Europe: one in the United Kingdom and the other in The Netherlands. The UK study, carried out from 1993 to 1996 involving 460,000 participants in the community presenting to general practice, estimated that only 1 of 136 cases of GI illness is detected by surveillance. The study indicated that as many as 1 in 5 people in the general UK population develop GI illness each year, with an estimated 9.4 million cases occurring annually of which about 50% are nonfoodborne.^{11,16} It was estimated that, for every 1 reported case of campylobacter, Salmonella, rotavirus, and norovirus, another 7.6, 3.2, 35, and 1562 cases, respectively, occur in the community; based on the number of laboratory reports, it is possible to estimate the true number of infections occurring in the community (Table 1).

From the community study carried out in The Netherlands between 1996 and 1999,¹⁷ it was estimated that approximately 1 in 3.5 people experience a bout of infectious GI disease each year. Campylobacter was detected most frequently (10% of cases), followed by *Giardia lamblia* (5%), rotavirus (5%), norovirus (5%), and Salmonella (4%). Relative to the population of The Netherlands (16 million), 650,000 norovirus gastroenteritis cases occur annually.¹⁸

The US study of Mead et al,¹² which also included data from community-based studies, indicated that the total number of cases of infectious GI illness annually is approximately 210 million (of which approximately 64% are nonfoodborne). They estimated that the number of episodes of acute gastroenteritis per person per year is approximately 0.79. From the available data, the authors were also able to estimate the proportion of total episodes that were nonfoodborne. As shown in Table 2, by far the most frequently reported causes of GI illness were norovirus, rotavirus, and campylobacter. For campylobacter, *E coli*, and norovirus, a significant proportion of cases was estimated as

Table 2. Estimated annual infectious gastrointestinal illnesses in the United States

	Total infectious GI illnesses	Infectious illnesses (%) that are nonfoodborne
Norovirus	23,000,000	13,800,000 (60)
Rotavirus	3,900,000	3,861,000 (99)
Campylobacter	2,453,926	490,785 (20)
Salmonella	1,412,498	70,624 (5)
Shigella	448,240	358,952 (80)
Hepatitis A	83,391	79,221 (95)
<i>E coli</i> O157	73,480	11,022 (15)

nonfoodborne, whereas, for hepatitis A (HAV), Shigella, and rotavirus, almost all cases were estimated as non-foodborne. For Salmonella on the other hand, only 5% of cases were considered as nonfoodborne. Davis et al reviewed outbreaks of *E coli* O157 related to family visits to animal exhibits.¹⁹

Indications are that norovirus is now the most significant cause of infectious GI illness in the developed world, both outbreak related and endemic.^{20,21} Currently, we are seeing increased outbreaks of norovirus, a major concern in Japan²² and also in Europe.²³ Expert opinion is that norovirus strains now circulating are more "virulent" and more easily spread from person to person via hands and surfaces or during food handling.²⁰

Infection with HAV is common worldwide,²⁴ and adenovirus is also a frequent cause of gastroenteritis. *C difficile*-associated disease now occurs with increasing frequency in the community, in which it usually affects persons receiving antibiotic therapy but also healthy individuals.²⁵ Recently, a new strain (O27) of *C difficile* has emerged in North America, causing infections in the community among individuals with no predisposing factors.²⁵ A recent study²⁶ indicated that exposure to a family member with *Helicobacter pylori* gastroenteritis was associated with a 4.8-fold increased risk of infection in another family member and that infection most usually involved person-to-person transmission, associated with conditions of crowding and poor hygiene.

Using data from the 2006 *E coli* O157:H7 outbreak in 2006 in the United States associated with contaminated spinach, Seto et al developed a model that showed that secondary person-to-person transmission was similar to that in previous *E coli* outbreaks ($\approx 12\%$). The model suggests that even a modestly effective hygiene promotion strategy to interrupt secondary transmission (prevention of only 2%-3% of secondary illnesses) could result in a reduction of $\approx 5\%$ to 11% of symptomatic cases.²⁷

Respiratory tract infections and hygiene

Respiratory tract infections are largely caused by viruses. In the United States, viruses account for up to 69% of respiratory infections.²⁸ The common cold is reported to be the most frequent, acute infectious illness to humans.²⁹ Data from the United States suggest that the mean number of respiratory illnesses experienced per year in adults is approximately 1.5 to 3.0, and, in children under 5 years of age, it is approximately 3.5 to 5.5.²⁸

Approximately 80% of upper RT infections are caused by rhinoviruses. Other species causing acute rhinitis are coronaviruses, parainfluenza viruses (PIV), respiratory syncytial viruses (RSV), and adenoviruses.³⁰ Although colds are generally mild and self-limiting, they represent a significant economic burden because of loss in productivity and medical costs. Furthermore, secondary infections produce complications, such as otitis media, sinusitis, or lower respiratory infections including pneumonia, with its risk of mortality, particularly in elderly adults. Several studies have demonstrated that colds are also a trigger for asthma.³¹ RSV is the major cause of viral RT infection in young children worldwide. Child day care attendance in North America carries with it a very high risk of RSV infection within the first 2 years of life and accounts for 0.5% to 1.0% of hospitalized infants in the United States.³²

Influenza is a more serious RT illness, which can cause complications that lead to increased physician visits, hospitalization, and death, the risks being highest among persons aged >65 years, children aged <2 years, and persons who have medical conditions (eg, diabetes, chronic lung disease).³³⁻³⁵ Influenza must also be considered in terms of days absent from work and school and pressure on health care services.³⁵ An important aspect of influenza is the threat associated with the emergence of novel subtypes capable of causing an influenza pandemic.³⁶ According to Bridges et al,³⁷ influenza epidemics in the United States result in an annual average of 36,000 deaths and 114,000 hospitalizations; among those with influenza who belong to an "at-risk" group, a significant proportion develop pneumonia, and up to 1 in 10 can die of related complications. In Europe, the 2004-2005 influenza season annual report³⁸ showed that, of 25 countries, 15 recorded what is regarded as high activity (150 up to 3000 influenza-like or acute respiratory illnesses per 100,000 population).

Although data indicating the role of hands and other surfaces in the transmission of colds have been available for some time, it is only in the last few years that there has been any real awareness that hands and surfaces may also be a transmission route for flu viruses.³² Evidence that measures such as hand hygiene can reduce spread of RT infections comes from

the SARS outbreaks in Hong Kong, which coincided with the latter part of influenza season, when it was observed that, as extensive personal and community public health measures took place, influenza case numbers fell significantly, more so than usual for the time of year.³⁹

Skin and wound infections and hygiene

Skin and wound infections are common in the home and community, but most are self-limited. Because these infections, apart from *S aureus* infections go unreported, little or no data are available on the burden of skin and wound infections in the community. *S aureus* is the most common cause of infections of skin and soft tissue, which, in a small proportion of cases, lead to the development of bacteremia or pneumonia.⁴⁰ Serious infections usually occur in health care facilities—in patients who are immunocompromised—in which *S aureus* is mostly usually associated with wounds and intravenous devices and in which the antibiotic-resistant strain, MRSA, is a major concern. Infected patients discharged from hospitals and health care workers (HCWs) caring for MRSA-infected patients can bring MRSA into the home and pass it on to healthy family members, who become colonized, thereby spreading the organism into the community and facilitating the circulation of these strains.⁴¹⁻⁴³ MRSA colonization in an individual can persist for up to 40 months.^{44,45}

In recent years, MRSA has been increasingly found to cause infections in healthy members of the community without apparent risk factors.²⁵ These CA-MRSA strains are different from health care-associated (HCA) MRSA strains and are a concern because they equally infect children and young adults. These strains primarily cause skin and soft tissue infections but can also cause invasive infections such as sepsis, pneumonia, and osteomyelitis, which in some cases can be fatal.²⁵ Some CA strains are known to produce Pantone-Valentine leukocidin (PVL), which has been implicated as a virulence factor,⁴⁶ although opinion is, however, divided as to whether this is the case; whereas some studies support this notion,⁴⁷ others do not.⁴⁸ In the United States, CA-MRSA is now a significant concern. CA-MRSA strains have also now been detected in France, Switzerland, Germany, Greece, the Nordic countries, Australasia, The Netherlands, and Latvia.²⁵ In the United Kingdom, cases of CA-MRSA and PVL-producing strains have been reported, but the number of reported cases is still small.^{25,49}

Health care and "at-risk" groups in the home

Key factors that contribute to changing ID trends are the social and demographic changes that are occurring

Table 3. Prevalence of “at-risk” persons in the domestic setting

	United States	United Kingdom	Germany	The Netherlands
Total population	290 million	60 million	82 million	16 million
Over 65 years of age	35.6 million	9 million	13 million	2 million
Living with cancer: significant proportion in the community, and undergoing chemotherapy	2 million	1 million	-	160,000
Under 1 year of age	35.6 million	600,000	800,000	100,000
Discharged from hospital within previous 2 weeks	1.25 million	200,000	-	60,000
Hospital outpatients at home	-	-	1,270,000	-
AIDS cases*	40,000	15,000	-	91
People in home care	0.5 million	-	-	-
Total “at-risk” persons	>1 in 7	>1 in 6	>1 in 5.6	>1 in 6.3

*This does not include those who are HIV positive, who may also have lowered resistance to infection.

within the global population that affect our resistance to infection. “At-risk” groups cared for at home include not only newborn infants whose immune system is not fully developed but also the rapidly increasing elderly population whose immune system is declining. “At-risk” groups include patients discharged recently from hospital, immunocompromised family members, and family members with invasive devices such as catheters. It also includes people whose immunocompetence is impaired as a result of chronic and degenerative illness or because they are undertaking certain drug therapies. All of these groups, together with those who carry HIV/AIDS, are increasingly cared for at home by a caregiver, who may be a household member. A survey of the United States and 3 European countries—Germany, The Netherlands, and the United Kingdom—suggests that up to 1 in 5 of the population belongs to an “at-risk” group (Table 3). The data suggest that between 12% and 18% of the population of these countries are >65 years of age. In an intervention study of 148 patients with AIDS, it was found that patients assigned to the intensive handwashing intervention group developed fewer episodes of diarrheal illness (1.24 ± 0.9 vs. 2.92 ± 0.6 new episodes of diarrhea, respectively, during a 1-year observation period.⁵⁰

GI pathogens are now implicated as causative or contributory factors in the development of cancers and other chronic conditions; examples include hepatitis B virus (hepatocellular carcinoma),⁵¹ *H pylori* (peptic ulcer disease),⁵² and *Campylobacter jejuni* (Guillain Barré syndrome).⁵³ Foodborne illness has been estimated to result in chronic sequelae in 2% to 3% of cases⁵⁴; a European Commission report⁵⁵ cites evidence of chronic disease, such as reactive arthritis, following 5% of Salmonella cases, with 5% of *E coli* O157 cases progressing to serious and even fatal complications. Even mild viral infections can be predisposing factors to more severe and possibly fatal secondary bacterial infections.⁵⁶

DEVELOPING A RISK-BASED APPROACH TO HOME HYGIENE

In devising a strategy for home hygiene and producing hygiene practice advice, the International Scientific Forum on Home Hygiene (IFH) has developed an approach based on risk management that involves identifying the “critical control points” for preventing the spread of ID in the home. Risk management (also known as Hazard Analysis Critical Control Points [HACCP]) is now the standard approach for controlling microbial risks in food and other manufacturing environments and is becoming accepted as the optimum means to prevent such risks in home and hospital settings.⁵⁷

The key feature of the IFH approach is that it recognizes the need to look at hygiene from the point of view of the family and the total range of problems it faces to reduce ID risks, including food hygiene, personal hygiene (particularly hands) and hygiene related to the general environment (toilets, baths, hand basins, surfaces, and others), domestic animals, and family members at increased risk. Adopting a holistic approach makes sense because all these issues are interdependent and based on the same underlying microbiologic principles. HACCP also forms the basis for developing an approach to home hygiene that can be adapted to meet differing needs. Indeed, it is only by adopting such a holistic approach that the causal link between hands and infection transmission in the home can be addressed properly because hand hygiene is a central component of all these issues.

The IFH risk management approach to hygiene starts from the principle that pathogens are introduced continually into the home by people (who may have infection or may be asymptomatic), food, and domestic animals and also sometimes via the water or the air. Additionally, sites at which stagnant water accumulates, such as sinks, toilets, waste pipes, or items, such as cleaning or face cloths, readily support microbial

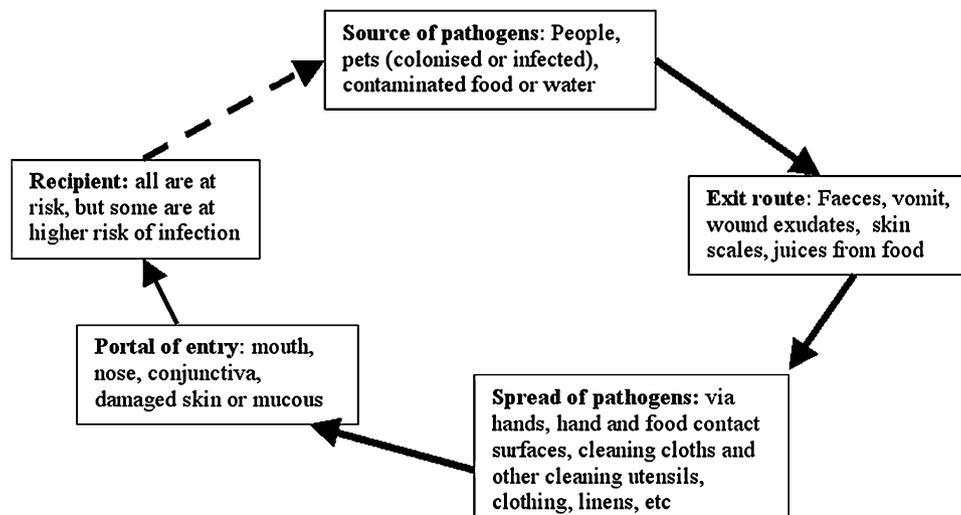


Fig 1. The chain of infection transmission in the home.

growth and can become a primary reservoir of infection; although microbial species are mostly those that represent a risk to vulnerable groups, primary pathogens can also be present.⁵⁸ So long as there are people, pets, and food in the home, there will always be the risk of pathogenic microbes. In many homes, there will also be at least one family member who is more susceptible to infection for one reason or another.

Within the home, there is a chain of events, as described in Fig 1, that results in transmission of infection from its original source to a new recipient. To an extent, we can limit the exit and entry of pathogens from and into the body, but the link that we have most control over is that related to the “spread of pathogens.” The spread of infection can be interrupted by good hygiene practice, which includes adherence to hand hygiene recommendations and cleaning and disinfecting contaminated environmental surfaces.

The risk-based approach to home hygiene is described in more detail by Bloomfield and Scott⁵⁹ and Bloomfield.⁶⁰ They suggest that sites and surfaces in the home should be categorized into 4 main groups: reservoir sites, reservoir/disseminators, hands and hand and food contact surfaces, and other surfaces. Risk assessment is then based on the frequency of occurrence of pathogenic contamination at that site, together with the probability of transfer from that site such that family members may be exposed. This means that, even if a particular environmental site is highly contaminated, unless there is a high probability of transfer from that site, the risk of infection transmission is low. From this, it is possible to determine the “critical control points” for preventing spread of infection. The data suggest the following:

- For reservoir sites such as the sink waste pipes or toilets, although the probability of contamination (potentially pathogenic bacteria or viruses) is high, the risk of transfer is limited unless there is a particular risk situation (eg, a family member with enteric infection and fluid diarrhea, when toilet flushing can produce splashing or aerosol formation that can settle on contact surfaces around the toilet).^{58,61}
- By contrast, for reservoir sites such as wet cleaning cloths, not only is there high probability of significant contamination, but, by the very nature of their usage, they carry a high risk of disseminating contamination to other surfaces and to the hands.
- For hands and hand contact and food preparation surfaces, although the probability of contamination is, in relative terms, lower, it is still significant, for example, particularly following contact with contaminated food; people; pets; or other contaminated surfaces such as door, faucet, and toilet-flush handles. Because there is a constant risk of spread from these surfaces, hygiene measures are important for these surfaces.
- For other surfaces (floors, walls, furniture, and others), risks are mainly due to pathogens such as *S aureus* and *C difficile*, which survive under dry conditions. Because the risks of transfer and exposure are relatively low, these surfaces are considered low risk, but where there is known contamination, for example, soiling of floors by pets, crawling infants may be at risk. Cleaning can also recirculate dust-borne pathogens onto hand and food contact surfaces.

Overall, this approach allows us to rank these various sites and surfaces (Fig 2) according to the level of

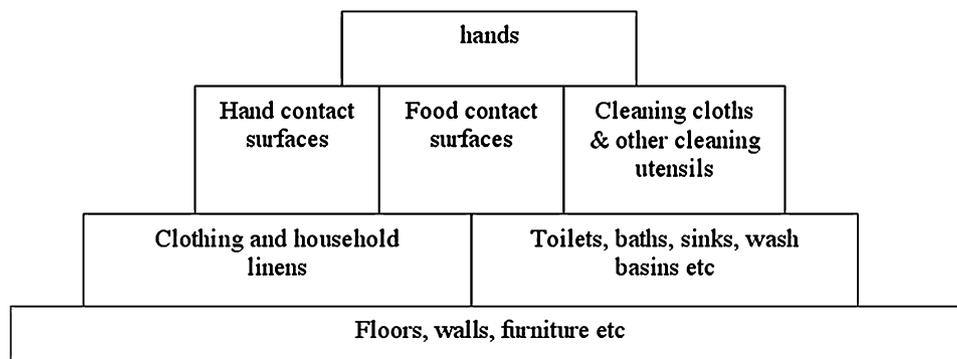


Fig 2. Ranking of sites and surfaces in the home based on risk of transmission of infections.

transmission risk; this suggests that the “critical control points” for breaking the chain of infection are the hands, together with hand and food contact surfaces, cleaning cloths, and other cleaning utensils. However, although this is a useful “rule of thumb” ranking, it is not a constant. For example, although risks from toilets, sinks, floors, and others relate mainly to the relatively lower risk of transfer from these sites to hands, hand and food contact surfaces, and cloths, this risk can increase substantially during occasions when an infected family member has fluid diarrhea or when a floor surface is contaminated with vomitus, urine, or feces. In the following section, we evaluate data indicating the extent to which the hands, both alone and in combination with other surfaces, are responsible for the spread of infection.

THE ROLE OF HAND HYGIENE IN PREVENTING INFECTION TRANSMISSION IN THE HOME AND THE COMMUNITY

The criteria for assessing causal inference of a link between hygiene practice and ID risk reduction have been reviewed by Aiello and Larson.⁶² Establishing the potential health impact of a hygiene intervention such as hand hygiene requires examination of the evidence related to a range of criteria that should include the strength, consistency, and temporality (cause and effect) of the association, together with data on plausibility (biologic or behavioral rationale) and biologic gradient. Aiello and Larson recognize that, although a single factor such as the hands may be a “sufficient cause” of infection transmission, spread of infection frequently involves a number of “component causes,” which, together or independently, work to determine the overall risk.

The risk assessment approach, as outlined above, indicates that the “critical control points” or “component causes” of infection transmission in the home are the hands, together with hand and food contact

surfaces and cleaning cloths. Based on plausibility, the role of the hands relative to other surfaces can be understood by mapping the potential routes of spread of GI, RT, and skin infections in the home as shown in Fig 3. This suggests that, for all 3 groups of infections, the hands are probably the single most important transmission route because in all cases they come into direct contact with the known portal of entry for pathogens (the mouth, nose and, conjunctiva of the eyes) and are thus the key last line of defense. Figure 3 shows, however, that, although in some cases the hands alone may be “sufficient cause” for transmission of an infection (eg, from an MRSA carrier, to hands, to the wound of a recipient), in other cases transmission involves a number of component causes (eg, from contaminated food, to a food contact surface, to hands, to the mouth of a recipient).

What this means is that the transmission risk via the hands also depends on the extent to which surfaces become contaminated with pathogens during normal daily activities, ie, the risk of hand-to-mouth transfer will be increased if extensive transfer from raw food to food preparation surfaces also occurs. Defining the importance of hand hygiene relative to other hygiene practices, such as surface and cloth hygiene, is difficult because of the close interdependence of these factors.

Although the focus of this review is the prevention of infection through hygiene practice, Fig 3 shows that in some cases airborne transmission can operate independently, without involving the hands, whereas, for GI infection, transmission can operate independently via food. Although handwashing intervention studies provide data supporting the causal link between hand contamination and ID transmission, defining the importance of hand hygiene relative to other hygiene practices, such as surface and cleaning cloth hygiene, or the risks associated with airborne transmission is difficult because of the close interdependence of these factors. Currently, such assessments can only be made on a qualitative basis, using microbiologic data

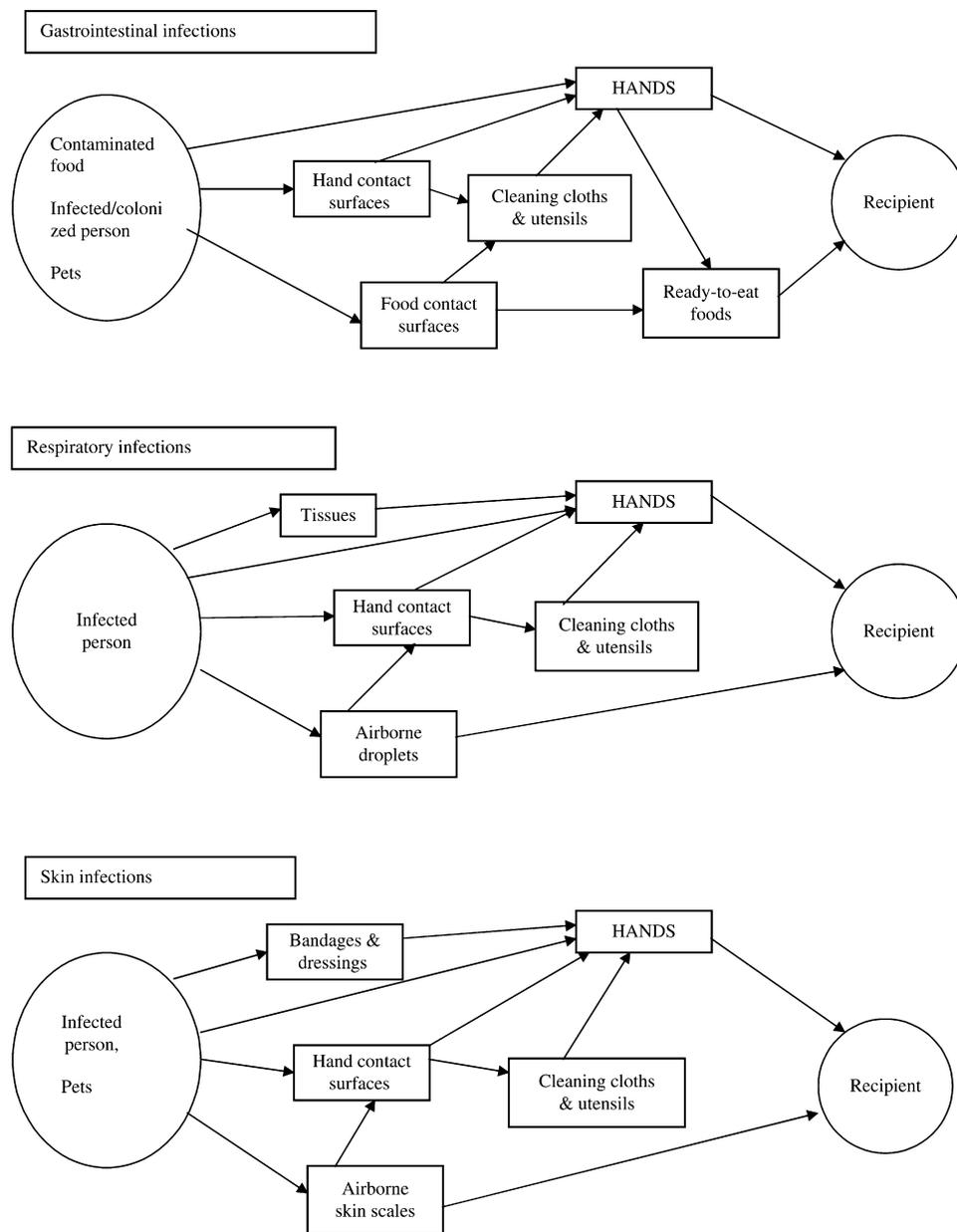


Fig 3. Routes of transmission of infections in the home.

(as in the following section) together with some limited epidemiologic data. In this section, we present epidemiologic and microbiologic data to support the causal relationship between hygiene and ID risk. Because the risks of hand transfer increase as the risks of contamination of other surfaces increases, data related to relevant surfaces are also included.

Microbiologic studies of the spread of pathogens via hands and other surfaces

In recent years, a range of studies has been published, many related specifically to the home, which

indicate the extent to which ID agents occur and are spread in home and community settings during normal daily activities and their potential to cause infection. These studies include assessments of frequency occurrence of sources of pathogens in the home, their rate of “shed” from an infected source into the environment, their rate of die away on hands and other surfaces, their rate of transfer via the hands to the mouth, nose, conjunctiva, and others and/or to ready-to-eat foods, and their the infectious dose. The infectious dose (ie, the number of particles to which the recipient is exposed), their immune status, and the route by which they are infected are key factors that determine

Table 4. Infectious doses for gastrointestinal pathogens

Organism	Infectious dose
<i>Salmonella</i> species	Up to 10^6 but could be as low as 10-100 cells. ⁶⁸ Contamination may be amplified by transfer to foods, which are then stored incorrectly.
<i>Campylobacter</i> species	500 organisms can result in human illness. ⁶⁹
<i>E coli</i> O157	Oral dose for <i>E coli</i> O157 may be as little as 10 cells. ⁷⁰ In one outbreak, a median dose of <100 organisms per hamburger was reported. ⁷¹
Norovirus	10-100 units or even less. ⁷²
Rotavirus	May be as few as 10 particles. ⁷³ Ward et al showed that 13 of 14 adults became infected after consuming rotavirus (10^3 particles) picked up from a contaminated surface via the hands. ⁷³

the infection risk. The “infectious dose” varies for different pathogens and is usually lower for people who are “at-risk” than for healthy household members.

Transmission of infectious GI disease. *Risks from exposure to GI pathogens via the hands.* As shown in Fig 3, exposure to GI pathogens can occur by direct hand-to-mouth contact or indirectly via contaminated food. In the home, food can be contaminated either directly by an infected food handler or indirectly by cross contamination via hands and surfaces from another source, which may be contaminated food, another infected household member (or carrier), or a household pet or farm animal. Hand-to-mouth contact is a frequent occurrence, particularly among children; a study of mouthing behavior in 72 young children showed that children <24 months of age exhibit the highest frequency, with 81 events/hour; for children >24 months of age, this was reduced but was still of the order of 42 events/hour.⁶³

The potential for transmission of pathogens from hands to ready-to-eat foods is supported by a number of studies:

- In a model domestic kitchen, 29% of food preparation sessions using campylobacter-contaminated chicken resulted in positive campylobacter isolations from prepared salads, cleaning materials, and food contact surfaces.⁶⁴
- Bidawid et al^{65,66} showed that touching lettuce with finger pads contaminated with HAV and feline calicivirus (FCV), used as a surrogate for norovirus, for 10 seconds resulted in transfer of 9.2% and 18%, respectively, of the virus. Based on the load for HAV in feces (10^6 to 10^9 viral particles/g), an estimated 1300 particles were transferred to the lettuce.
- Rusin et al showed that, when volunteers’ fingertips were inoculated with a pooled suspension of *Micrococcus luteus* (*M luteus*), *Serratia rubidea* (*S rubidea*), and bacteriophage PRD-1 and held to the lip area, transfer rates were 40.99%, 33.97%, and 33.90%, respectively.⁶⁷

As stated above, the infection risk from oral consumption depends on the number of bacterial cells or

viral particles that are consumed. Table 4 shows that, for many of the commonly occurring GI pathogens, the infectious dose is relatively small.

Sources and spread of GI pathogens to the hands. Figure 3 illustrates that the risk of exposure to GI pathogens via the hands depends on the extent to which these pathogens are brought into the home (either by infected people or pets or via contaminated food) and the extent to which they are spread via hands and other surfaces and by airborne transmission. Relevant data from various sources, as summarized below, suggest that exposure to GI pathogens via the hands is a frequent occurrence during normal daily activities and that the numbers of organisms transferred by hand-to-mouth contact can be well within the numbers required to cause infection.

Household members who are infected, or who are carriers, are a primary source of infection in the home. Pathogens that can be carried persistently by otherwise healthy people include *Salmonella* species and *C difficile*. Approximately 3% of adults (mainly those >65 years of age), and up to two thirds of babies, are known to carry *C difficile* in their gut, although it is not known what proportion are toxin producing.²⁵ People or animals that carry GI pathogens shed large numbers of organisms in their feces or when they vomit. A single vomiting incident following norovirus infection may produce 30 million viral particles,⁷² and, at the peak of a rotavirus infection, > 10^{11} virions may be excreted per gram feces.⁷⁴ Surfaces in the home may become contaminated by enteric organisms that are aerosolized during vomiting or by transfer of vomitus and fecal matter via hands. Viruses aerosolized from flushing the toilet can remain airborne long enough to contaminate surfaces throughout the bathroom.⁷⁵

Infectious agents introduced into the home via food include *Salmonella*, campylobacter, listeria, and *E coli* O157. A variety of foods can act as a source of these organisms, including meat, fish and poultry products, dairy products, fruits, and vegetables. Organisms in particles, and moisture or juices, from food will contaminate any surface they come into contact with. An

EFSA survey⁷⁶ of Salmonella in chicken indicates significant differences among EU member states, with isolation rates between 0% and 68.2%; the level reported for the United Kingdom was 7.1% to 9.4%. The EFSA also reported that up to 66% of samples from fresh poultry were positive for campylobacter.⁷⁷ In the United States, more than half of raw chicken is estimated to be contaminated with campylobacter.⁷⁶ Chapman et al⁷⁸ showed that 0.4% to 0.8% of meat products purchased from UK butchers were positive for *E coli* O157. In a recent study in Canada, *C difficile* was isolated from 20% of 60 samples of retail ground meat purchased over a 10-month period, and 11 isolates were toxigenic.⁷⁹

The home is frequently a shelter to a range of different pets; more than 50% of homes in the English-speaking world have cats and dogs, with 60 million cats and dogs in the United States. In the United States, up to 39% of dogs may carry campylobacter, and 10% to 27% may carry Salmonella⁸⁰; cats are also carriers of these organisms. Carriage of *C difficile* in household pets is quite common; up to 23% of pets are affected, although these mostly involve noncytotoxic strains.²⁵

Kramer et al,⁸¹ Sattar et al,⁸² and Rzezutka and Cook⁸³ reviewed data showing that GI pathogens can survive on surfaces for several hours and, in some cases, days, particularly on moist surfaces, although infectivity depends on the numbers that survive (Table 5).

Studies to quantify transfer between hands, foods, and kitchen surfaces^{67,84} showed that transfer rates were highly variable, ranging from as high as 100% to as low as 1%. Transfer to hands was highest from non-porous surfaces but lower from surfaces such as carrots, sponges, and dishcloths (<1%). Rusin et al⁶⁷ sampled volunteers hands after touching surfaces contaminated with *M luteus*, *S rubidea*, and phage PRD-1. Activities included wringing out a dishcloth/sponge, turning off a faucet, cutting up a carrot, making hamburger patties, holding a phone receiver, and removing laundry from the washing machine. Transfer efficiencies for the phone receiver and faucet were 38% to 65% and 27% to 40%, respectively. Paulson⁸⁵ showed that, when gloved hands were contacted for 5 to 10 seconds with surfaces such as cutting boards and doorknobs contaminated with FCV (log 5.9 particles), the log number of particles recovered from hands was 4.7 to 5.4.

These laboratory studies are supported by a range of field studies showing spread via the hands and other surfaces during normal daily activities:

- Following preparation of Salmonella and campylobacter-contaminated chickens in domestic kitchens, these species were isolated from 17.3% of hands

Table 5. Persistence of gastrointestinal pathogens on dry inanimate surfaces

	Duration of persistence (range)
Type of bacteria	
<i>Campylobacter jejuni</i>	Up to 6 days
<i>C difficile</i> (spores)	5 months
<i>Escherichia coli</i>	1.5 hours to 16 months
<i>Helicobacter pylori</i>	Less than 90 minutes
Listeria species	1 day to months
Salmonella species	1 day
Shigella species	2 days to 5 months
Type of virus	
Norovirus and feline calicivirus	8 hours to 7 days
Rotavirus	6-60 days

and hand and food contact surfaces. Isolation rates were highest for hands, chopping boards, and cleaning cloths (25%, 35%, and 60%, respectively, of surfaces sampled).⁸⁶

- In homes containing an infant recently vaccinated for polio (during which time shedding occurs in feces), virus was isolated from 13% of bathroom, living room, and kitchen surfaces.⁸⁷ Most frequently contaminated were hand contact sites such as bathroom taps, door handles, toilet flushes, soap dispensers, nappy changing equipment, and potties.
- Following handshaking with a volunteer whose hands were contaminated from touching a virus-contaminated door handle, successive transmission from one person to another could be followed up to the sixth person.⁸⁸
- Where fingers were contacted with norovirus-contaminated fecal material, the virus was consistently transferred via the fingers to melamine surfaces and from there to hand contact surfaces, such as taps, door handles, and telephone receivers. Contaminated fingers sequentially transferred the virus to up to 7 clean surfaces.⁸⁹
- A study⁹⁰ with FCV showed survival for up to 3 days on telephone buttons and receivers, for 1 or 2 days on computer mouse, and for 8 to 12 hours on keyboard keys and brass disks representing faucets and door handles. The time for 90% virus reduction was <4 hours on computer keys, mouse, and brass disks; 4 to 8 hours on telephone receivers; and 12 to 24 hours on telephone buttons.
- In homes of infants with recurrent *C difficile* infection, 12% of environmental surfaces were positive for *C difficile*, and 1 of 4 other household members carried *C difficile* in stool. In a control home with no household carriers, none of 84 environment samples were positive for *C difficile*.⁹¹
- In 4 out of 6 homes in which there was a Salmonella case, the causative species was isolated from fecal

soiling under the flushing rim and scale material in the toilet bowl for up to 3 weeks after notification of infection.⁵⁸ Flushing toilets seeded with *Salmonella enteritidis* resulted in contamination of hand contact surfaces such as toilet seats and toilet seat lids.

These represent recent examples of studies that have been reported. These and other studies are also reviewed elsewhere.^{82,92-94}

In developing hygiene policies for preventing GI infections, one of the difficulties is assessing risks associated with hand transmission relative to other risks such as inadequate cooking or storage of food or inhalation of infected vomit particles. Gillespie et al¹⁵ reported an evaluation of reported outbreaks linked to UK households for 1992 to 1999 that suggested, of the 85% of outbreaks designated as foodborne, cross contamination was implicated in 20% of outbreaks compared with 30% and 31% of outbreaks for which inadequate storage and cooking, respectively, were thought to be the cause. There were no data to suggest what percentage of cross contamination events involved the hands, and Gillespie et al¹⁵ expressed concern that most of the reported outbreaks were linked to home catering, thus not necessarily representative of normal daily routine. Aerosol transmission can result from settling on hand and food contact surfaces, but, for norovirus, infection can sometimes result from direct inhalation of infected particles of vomit by people immediately adjacent to the person who vomits. The potential for airborne transmission of norovirus was demonstrated in studies in a restaurant and a primary school, in which close proximity to infected persons in the immediate aftermath of a vomiting attack was identified as a risk factor.^{95,96}

Transmission of RT infections. The last 2 years have seen an unprecedented global focus on developing strategies for preventing transmission of influenza. The WHO⁹⁷ is taking a lead on pharmaceutical interventions such as vaccines and antivirals but has also made recommendations for other interventions,⁹⁸ which include highlighting the importance of hygiene, and in particular hand hygiene, in minimizing spread in the home and community.

Risks from exposure to respiratory pathogens via the hands. As shown in Fig 3, exposure to RT viruses can occur either by inhalation of infected mucous or inoculation of the nasal mucosa or eyes with virus-contaminated hands, which then cause infection via the mucous membranes and upper RT. Rhinovirus and RSV are deposited into the front of the nose or into the eye (where they pass down the lacrimal duct), either on the end of the finger or possibly sometimes in aerosolized droplets.⁹⁹ Rubbing the eyes and nose with the fingertips is a common occurrence; Hendley et al found that 1 in 2.7 attendees of hospital

Table 6. Infectious doses for viruses that cause respiratory diseases*

Virus	Minimal infectious dose associated with intranasal inoculation
Respiratory syncytial virus	100-640 TCID ₅₀
Rhinovirus	0.032-0.4 TCID ₅₀ ; also cited as 1-10 TCID ₅₀
Influenza	2-790 TCID ₅₀
Parainfluenza	1.5-80 TCID ₅₀

*From Boone and Gerba.⁹⁴

rounds rubbed their eyes, and 33% picked their nose, within a 1-hour observation period.¹⁰⁰

A review of the data⁹⁴ (Table 6) suggests that the infectious dose for respiratory viruses is relatively small. Alford et al suggest that aerosolized doses of as little as 1 TCID₅₀ (tissue culture infective dose) of influenza virus could infect volunteers.¹⁰¹

Evidence for transmission of rhinovirus and RSV infections via contaminated hands comes from a number of studies:

- A number of studies have demonstrated that self-inoculation by rubbing the nasal mucosa or conjunctivae with rhinovirus-contaminated fingers can lead to infection.^{100,102} Over a period of 10 years, Gwaltney and Hayden performed intranasal challenges on 343 healthy young adults who had no antibody to the challenge, and infected 321 (95%).¹⁰³ After handling contaminated coffee cups and other objects, more than 50% of subjects developed infection.¹⁰⁴ Hall et al showed that volunteers touching contaminated objects and/or the fingers of symptomatic individuals had a higher attack rate of colds if they touched their eyes or nose.¹⁰⁵
- In a 4-year family trial, Hendley and Gwaltney¹⁰⁴ found that prophylactic treatment of mothers' fingers with iodine reduced the incidence of RT infections. When illness occurred in the family, mothers were instructed to dip their fingers in iodine upon awakening in the morning, then every 3 or 4 hours or after activities that washed the iodine from the skin. The secondary attack rate in mothers was 7% in the iodine group and 20% in placebo families. No infections occurred in mothers after 11 exposures to an infected index case in the iodine group, compared with 5 infections after 16 exposures in the placebo group.
- Hall et al showed that infected infants excrete prodigious amounts of RSV in their nasal secretions for several days¹⁰⁵ and that RSV could be recovered from hands that had touched surfaces contaminated with secretions from infected infants.⁹⁹ Hall and Douglas found that close contact with symptomatic infants who were producing abundant secretions,

or their immediate environment, was necessary for infection.¹⁰⁶

Sources and spread of RT pathogens to the hands. Figure 3 illustrates that the risk of exposure to RT pathogens via hands depends on the extent to which these pathogens are spread from an infected person during normal daily activities. Relevant data come from various sources and are summarized below. Taken together, the data suggest that, when a household member is infected, exposure of other household members via hands is likely to occur during normal daily activities and that the numbers of organisms involved are within those required to initiate infection if transferred to the eyes or nose.

People infected with cold viruses shed large quantities of virus-laden mucus. Droplets of nasal secretions generated by coughing, sneezing and talking can travel over a distance >3 m to contaminate surrounding surfaces.^{37,98,107-109} Up to 10⁷ infectious influenza particles per milliliter has been detected in nasal secretions.¹¹⁰ The mean duration of a cold is 7.5 days. Viral shedding may occur 24 to 48 hours before illness onset but generally at lower titers than during the symptomatic period. Titers generally peak during the first 24 to 72 hours of illness and decline within several days, with titers low or undetectable by day 5. Children can shed virus for up to 3 weeks, whereas immunocompromised people may continue to shed virus for weeks to months.⁹⁸

Infectious material can also be deposited directly on hands and tissues during sneezing and blowing the nose. Contamination of hands can occur by handshaking or touching contaminated surfaces. Pathogens shed into the environment from these sources can survive for significant periods and are readily spread around the home to and from the hands and via handkerchiefs and tissues, tap and door handles, telephones, or other hand contact surfaces:

- Gwaltney and Hendley demonstrated that most subjects with experimental colds had rhinovirus on their hands and that virus could be recovered from 43% of plastic tiles they touched.¹⁰⁴ For people with rhinovirus colds, virus was found on 39% of hands and 6% of objects in their immediate environment.¹⁰⁰ Reed demonstrated recovery of virus from naturally contaminated objects in the surroundings of persons with rhinovirus colds.¹⁰²
- In a recent study, Winther et al¹¹¹ recruited volunteers suffering from colds to stay overnight in hotel rooms. After checkout, but before room cleaning, 10 objects identified as frequently touched were sampled for rhinovirus. Virus was found on 35% of objects, including door handles, light switches, pens, faucet and toilet handles, and television

remote controls. Some people contaminated none or few sites, most contaminated several, and some contaminated almost all (up to 8) sites. In a second study in which the same subjects stayed overnight in a hotel room in which hand contact surfaces (light switch phone button and handset) had been contaminated with rhinovirus-contaminated mucus, 60% of subjects became contaminated with rhinovirus.

- Ansari et al showed that hands readily pick up rhinovirus and PIV by touching contaminated objects.¹¹² As much as 70% of infectious rhinovirus has been shown to transfer to a recipient's fingers after contact for 10 seconds.¹¹³ In a study with volunteers who handled contaminated doorknobs or faucets, recovery rates from 3 to 1800 plaque-forming units of rhinovirus were obtained from fingertips.¹¹⁴
- In a study of US day care centers and domestic homes, influenza A virus was detected on 23% of day care center surfaces sampled during the fall of 2003 and 53% of surfaces sampled during the spring. Although no influenza was detected on home surfaces during the summer, influenza was detected on 59% of surfaces sampled during March in 5 homes in which there was an influenza-infected child. No virus was recovered from 3 other homes in which all household members were healthy. Influenza virus was recovered most frequently from telephone receivers (80%) and least frequently from computer keyboards (40%). Other surfaces found to be contaminated included refrigerators; kitchen faucets; light switches; microwaves; TV remote controls; doorknobs; and bath, faucet, and toilet handles. Influenza virus was recovered from 69% of the day care center diaper changing areas, indicating presence of virus in infant feces.⁹⁴

Transfer of RT infections via contaminated hands depends on the ability of the virus to survive and retain its infectivity outside the human host. The potential for survival varies significantly between nonenveloped rhinovirus and RSV, compared with the enveloped influenza virus and PIV:

- Kramer et al⁸¹ and Hendley et al¹⁰⁰ review data showing that rhinovirus and RSV can survive for significant periods (2 hours to 7 days for rhinovirus, up to 6 hours for RSV) on dry surfaces and for at least 2 hours on human skin.
- Ansari et al¹¹⁵ and Brady et al¹¹⁶ showed that, although PIV can survive on nonabsorbent surfaces for up to 10 hours, survival on hands was relatively poor (1-2 hours).
- Bean et al¹¹⁷ showed that influenza virus could survive up to 24 to 48 hours on nonporous surfaces and up to 8 to 12 hours on cloth, paper, and tissues. By contrast, virus could be recovered from hands for only 5 minutes and then only if hands were contaminated with

high viral titers. Virus could be transferred from nonporous surfaces to hands for 24 hours and from tissues to hands for 15 minutes. Higher humidity shortened virus survival. Virus on nonporous surfaces could be transferred to hands 24 hours after the surface was contaminated, whereas tissues could transfer virus to hands for 15 minutes after the tissue was contaminated. On hands, virus concentration fell by 100- to 1000-fold within 5 minutes after transfer.

Opinion as to the importance of the hands relative to the airborne route for transmission of rhinovirus colds is divided. Some investigators^{30,99,103,104} maintain that contamination of the hands followed by inoculation of the eyes or nose is of paramount importance; in fact, Gwaltney et al found that it was exceedingly difficult to transmit virus orally or by kissing and found little evidence of droplet or droplet nuclei transmission.^{100,113} Others maintain that the evidence favors droplet and droplet nuclei transmission as the most important mode of spread.¹¹⁸ For RSV, there is general agreement that the hands are the primary route for the spread of infection.^{32,105,106}

For influenza, although more data are needed, it is increasingly accepted that not only airborne (both true airborne transmission involving droplet nuclei [$<5 \mu\text{m}$ in diameter] and “droplet transmission” involving droplets $>10 \mu\text{m}$ that deposit onto surfaces quite rapidly) but also surface (including hand) transmission come into play.^{98,119,120} The relative contribution of each mode of transmission is unknown but appears to vary depending on the circumstances, symptoms, respiratory tract loads, and the viral strain.¹²¹ Data from animal studies and influenza outbreaks suggest that droplets generated when infected persons cough or sneeze are the predominant mechanism of airborne transmission,³⁷ although data supporting droplet nuclei spread are also available.^{101,122-124} It is possible, however, that influenza is less transmissible via hands and surfaces compared with rhinovirus and others because of its lower ability to survive outside a human or animal host. Data suggest that, to some extent, airborne droplets and droplet nuclei cause infection as a result of settling on hand contact surfaces. The frequent occurrence of diarrhea and the detection of viral RNA in fecal samples tested suggest that the H5N1 influenza virus may replicate in the human gut and could be a source of transmission via hands and surfaces.¹²⁵ At present, however, it is thought that this is unlikely. The growing evidence base related to the survival, transmission, and human exposure to RT viruses via hands and other surfaces is also reviewed elsewhere.^{32,35,37,82,94,99}

Transmission of skin and wound infections. *Risks from exposure to skin and wound pathogens via the*

hands. As shown in Fig 3, exposure to skin pathogens such as *S aureus* can occur via the hands. Exposure can produce colonization and/or infection that usually occurs in areas in which there are cuts, abrasions, and others that damage the integrity of the skin. Where there are predisposing factors, the numbers of organisms required to produce infection may be relatively small. Marples¹²⁶ showed that up to 10^6 cells may be required to produce pus in healthy skin, but as little as 10^2 may be sufficient in areas in which the skin is occluded or traumatized. Risks associated with exposure to HCA-MRSA and CA-MRSA are different. HCA-MRSA usually affects elderly adults and those who are immunocompromised, particularly those with surgical or other wounds or who have indwelling catheters. For CA-MRSA, those at particular risk appear to be younger, generally healthy people who practice contact sports or other activities that put them at higher risk of acquiring skin cuts and abrasions.¹²⁷ US experience suggests that CA-MRSA may be more virulent than other strains and is easily transmissible within households and community settings (eg, schools, day care centers, sport teams) in which skin-to-skin contact or sharing of contaminated items (eg, towels, sheets and sport equipment) are vehicles for person-to-person transmission.¹²⁸ A case-control study¹²⁹ involving 55 cases of MRSA in a US prison showed that inmates who washed their hands ≤ 6 times per day had an increased risk for MRSA infection compared with inmates who washed their hands >12 times per day.

Sources and spread of skin and wound pathogens to the hands. Figure 3 illustrates that the risk of exposure to skin pathogens via the hands depends on the extent to which people or animals colonized or infected with pathogenic strains are present in the home and the extent to which these pathogens are spread during normal daily activities. Transfer of skin pathogens to the hands can occur either by direct contact with an infected source or indirectly via hand contact surfaces or the surfaces of clothing or household linens. Relevant data, as outlined below, suggest that, when there is a person in the home who is infected or colonized with *S aureus*, exposure of other household members as a result of transfer via hands, surfaces, clothing, and others is likely to occur during normal daily activities and that the numbers of organisms involved are within the numbers of particles that could initiate an infection in a susceptible recipient.

A study by Kluytmans et al suggests that *S aureus* is carried as part of the normal body flora in up to 60% of the general population,¹³⁰ although a 2006 US study¹³¹ suggests that the carriage rate is much less (31.6%). In the United Kingdom, indications are that the proportion of the general population carrying antibiotic-resistant strains of *S aureus* (either HCA- or CA-MRSA) is

somewhere between 0.5% and 1.5%, the majority being carriers of HCA-MRSA who are >65 years of age and/or have had recent association with a health care setting.¹³² Although cases of CA-MRSA and PVL-producing MRSA have been reported, indications are that the prevalence of MRSA and PVL-producing strains circulating in the community is currently very small.²⁵

In the United States, although it is concluded that colonization rates for MRSA in the community are still low, it is nonetheless thought to be increasing.^{127,133} Graham et al¹³¹ report on an analysis of 2001-2002 data from the National Health and Nutrition Examination Survey (NHANES) to determine colonization with *S aureus* in a noninstitutionalized US population. From a total of 9622 participants, it was found that 31.6% were colonized with *S aureus*, of which 2.5% were colonized with MRSA. Of persons with MRSA, half were identified as strains containing the SCCmec type IV gene (most usually associated with CA-MRSA), whereas the other half were identified as strains containing the SCCmec type II gene (most usually associated with HCA-MRSA). Several other investigators have examined the epidemiology of MRSA in the US community; differences in the data suggest a sporadic distribution of CA-MRSA, with carriage rates ranging from 8% to 20% in Baltimore, Atlanta, and Minnesota¹²⁷ up to 28% to 35% for an apparently healthy population in New York.¹³⁴

Domestic pets can also be a source of *S aureus*, including MRSA and PVL-producing strains.¹³⁵⁻¹³⁹ Manian¹³⁶ described 2 dog owners suffering from persistent MRSA infection, who suffered relapses whenever they returned home from the hospital; further investigation revealed that the dog was carrying the same strain of MRSA.

People who carry *S aureus* can shed the organism in large numbers most usually associated with skin scales.¹⁴⁰ Kramer et al⁸¹ review data showing that *S aureus* (including MRSA) can survive on dry surfaces for periods from 7 days up to 7 months. Scott and Bloomfield showed that, during a 4-hour drying period, up to 50% of *S aureus* inoculated onto laminate could be transferred to fingertips by contact. Transfer to fingertips also occurred when a cloth contaminated with *S aureus* was used to wipe a clean surface.¹⁴¹

Studies in health care settings, as reviewed by Bloomfield et al,²⁵ show that, where there is an infected or carrier individual, MRSA can be isolated from environmental surfaces frequently touched by hands including computer keyboards, pens, television sets, clothing, mattresses, pillows, beds and chairs, and door handles. These data are supported by studies, directly related to the home, showing the potential for spread of *S aureus* via hands and other surfaces during normal daily activities:

- In studies by Reynolds and Gerba¹⁴² and by Scott (Elizabeth Scott Centre for Hygiene and Health, Simmons College, Boston, personal communication) carried out in 27 and 35 US homes, respectively, including homes containing children and HCWs, MRSA was identified at one or more sites in 40% and 20%, respectively, of homes. Contaminated surfaces included bathroom rugs, bed linens, furniture, draperies, pet beds and food dishes, kitchen sink, countertop, kitchen faucets, kitchen drain, sponge/counter wiping cloth and dish towels, and infant high chair tray.
- In studies of HCWs colonized with MRSA,^{135,143-146} the HCW was treated to eradicate the organism but subsequently became recolonized. In each case, MRSA was isolated from environmental surfaces in the home of the HCW, including door handles, a computer desk shelf and computer joystick, linens, furniture, and in some cases also from other family members¹⁴³⁻¹⁴⁶ and family pets.¹³⁵
- A number of cases are reported in which family members in the home of an infected person have become colonized.¹⁴⁷⁻¹⁵⁰ Hollis et al¹⁴⁷ found that transmission of the MRSA strain from an index case to 2 siblings and the mother occurred at least 3 times, and one family member was colonized for up to 7 months or more.

These represent recent examples of studies that show survival and transfer of MRSA around the home. These and other studies are also reviewed by Bloomfield et al.²⁵

Intervention studies to establish the causal link between hand hygiene and infectious disease in the home and community

Both observational and interventional study designs have been used to assess the relationship between hand hygiene and ID transmission. By definition, observational studies are not randomized and must utilize careful methods to preserve internal validity. Control of confounding and the potential for selection, recall, and other biases are also a concern, for example, individuals who wash their hands less frequently are also less likely to report symptoms. Intervention studies on the other hand compare infection rates in groups in which handwashing is, or is not, promoted. Intervention studies employing randomization of treatment groups have been considered the "gold-standard" in terms of reducing selection biases. These studies have the ability to ensure that randomized groups are similar, apart from treatment allocation and differences that occur by chance. For these reasons, we limit discussion to intervention studies, focusing on GI and RT

Table 7. Intervention studies evaluating the impact of hand hygiene education or handwashing on reductions in infectious illnesses

Intervention	Setting, country	Outcome measured	Result, % reduction (95% CI)	Statistical significance	Reference
HW + HE	Child care, United States	Diarrhea	48 (0.23-0.65)	Yes	Black et al, 1981 ¹⁵⁵
HW + HE	Child care, United States	Diarrhea	12 (-0.10-0.30)	No	Bartlett et al, 1988 ¹⁵⁶
HW	Elementary school, United States	Gastrointestinal symptoms	57 (0.27-0.75)	Yes	Master et al, 1997 ¹⁵⁷
HW + HE	Child care, Canada	Diarrhea	-10 (-0.50-0.19)	No	Carabin et al, 1999 ¹⁵⁸
HW + HE	Child care, Australia	Diarrhea	50 (0.32-0.64)	Yes	Roberts et al, 2000 ¹⁵⁹

HW + HE indicates that the intervention arm received a hygiene education component that included handwashing; HW indicates that increased frequency or a scheduled handwashing was the only difference between the intervention and control group. HW, handwashing; HE, hygiene education; CI, confidence interval.

illnesses, because these are the most common infectious illness symptoms in home and community settings.

A range of intervention studies have been carried out to evaluate the causal link between handwashing and ID transmission and have been reviewed in a series of papers to assess the consistency and strength of the link.¹⁵¹⁻¹⁵³ Overall, these studies indicate a strong and consistent link between handwashing and GI disease and a significant link between handwashing and RT illnesses. For the most part, these studies have been carried out in child day care centers, schools, and military and other public settings in which the outcome is often measured against a high baseline level of infection. Relatively few studies have been carried out in household settings in the United States and Europe. Difficulties associated with studying households in developed areas include fewer children under the age of 5 years, higher level of hygiene infrastructure, and difficulties in collecting data. Given that there are likely fewer susceptible individuals clustered within household settings, the prevalence of GI and RT illnesses is relatively much lower, making it more difficult to detect a significant influence of hand hygiene on the occurrence of illness.

Whereas some intervention studies are not relevant to this review and have been omitted, others give useful insight into the potential impact of handwashing in the home and in the general community. Studies that are included have been selected on the basis of whether transmission routes are likely to reflect those in the home, most particularly whether the relative rates of transmission via these routes (as shown in Fig 2) are likely to be similar. For this reason, studies on GI infection in developing countries have been excluded; in these settings, limited access to sanitation means that rates of direct hand-to-mouth transmission from feces is high relative to other routes of transmission (eg, person-to-person transmission via hands, or inadequate food hygiene),

compared to settings with adequate water and sanitation in which transmission is more likely to involve person-to-person transmission and transmission via food, rather than direct feces-to-hand-to-mouth. For GI illnesses, we have, therefore, focused on studies carried out in developed country communities, although, even for studies such as those in child daycare centers, in which food preparation is not undertaken by study participants, the data probably reflect mainly the impact on person-to-person transmission. For RT infections, studies conducted in both developed and developing countries are included on the basis that relative rates of airborne transmission versus transmission via hands are likely to be similar regardless of setting.

In a recent review, Aiello et al assessed the relationship between handwashing and GI outcomes¹⁵⁴ focusing on studies conducted in North America and Europe. Table 7 summarizes studies providing an effect estimate (risk ratio, rate ratio, and others) as well as 95% confidence intervals (95% CI). In all of the studies, handwashing with soap was the factor studied, although in some, this was combined with hygiene education measures. All studies assessing handwashing and hand hygiene education were conducted in school or day care settings.

Among the studies in Table 7, the reduction in GI illness associated with handwashing ranged from -10% to +57%. However, 3 of the 5 studies were not statistically significant, including the study that identified a value of -10%. The studies that gave statistically significant results all describe reductions close to 50%. Overall, these reviews suggest a consistent causal relationship between handwashing and reduction in GI illness, although the findings are less consistent and of a lesser magnitude than in lesser developed settings in which studies considered statistically significant suggested reductions from 26% to 79%.¹⁵⁴

In assessing RT infections, the reviews of Aiello and Larson¹⁵¹ and Aiello et al,¹⁵⁴ mentioned above,

Table 8. Intervention studies evaluating the impact of hand hygiene education or handwashing on reductions in respiratory illnesses

Intervention	Setting, country	Outcome measured	Result, % reduction (95% CI)	Statistical significance	Reference
HE	Elementary school, United States	Respiratory illness-related Absenteeism	53 (-1.38-0.91)	No	Kimel, ¹⁶³ 1996
HW + HE	Elementary school, United States	Respiratory illness-related Absenteeism	21 (-0.02-0.39)	No	Master et al, ¹⁵⁷ 1997
HE	Child care, United States	Colds	32 (-0.04-0.56)	No	Niffenegger, ¹⁶⁴ 1997
HE	Child care, Canada	Respiratory	20 (0.07-0.32)	Yes	Carabin et al, ¹⁵⁸ 1999
HE	Child care, Australia	Respiratory	5 (-0.01-0.11)	No	Roberts et al, ¹⁶⁵ 2000
HW + HE	Community, Pakistan	Acute respiratory tract infections	51 (0.49-0.53)	Yes	Luby et al, ¹⁶⁶ 2005

HW, handwashing; HE, hygiene education; CI, confidence interval.

examined both RT and GI illness outcomes, whereas 3 other systematic reviews focused solely on the relationship between hand hygiene and RT infections. A review by Lee et al, assessing the relationship between several nonvaccine interventions and prevention of acute RT infection,¹⁶⁰ concluded that the promotion of hand hygiene may be useful for preventing RT disease. Rabie and Curtis in 2006 also published a review of hand hygiene studies involving RT infections.¹⁶¹ They reported that hand hygiene (handwashing, education, and waterless hand sanitizers) can reduce the risk of respiratory infection by 16% (95% CI: 11%-21%). These investigators have now updated their estimate with 2 further, more recent, studies that, when all studies are taken together, give a pooled impact on respiratory infection of 23%.¹⁶²

Based on these studies, Table 8 summarizes the results of community-based interventions (excluding health care-related and military settings) on RT illnesses. Most studies were conducted in economically developed countries (83%, 5/6). The range of reduction in illness was 5% to 53%, but only 33% (2/6) of the studies were statistically significant. The results suggest that hand hygiene education and promotion of handwashing can reduce rates of RT illnesses, but the impact is less than for GI infections, although it must be borne in mind that the available data are more limited.¹⁵⁴

There are also several studies of handwashing that do not distinguish between GI and RT outcomes.^{157,167,168} These studies measure outcomes such as illness-related absenteeism, making it difficult to assess the impact on specific disease etiologies. Of these studies, only one reported a significant reduction (25%).¹⁵⁷ Two were conducted in day care centers, and 1 was conducted in an elementary school. All 3 studies were conducted in economically developed areas (United States, Sweden, and Israel).^{157,167,168}

Several methodologic issues must be considered for these studies. Studies that use randomization are more

likely to produce study groups with similar baseline characteristics. Surprisingly, 40% of the 11 studies in Tables 7 and 8 did not randomize. In some studies, randomization may not be an option (eg, in community settings) because the intervention is too complicated to randomize to multiple groups rather than assigning it to a single geographic area. Controlling for potential confounding variables is also an important issue, for example, if a study did not control for age and included adults as well as children, the effect of a hygiene intervention may be diluted because adults are at lower risk for diarrheal disease compared with children. In randomized studies, adjustment for confounding in the statistical analysis may not be required if potential confounders associated with intervention and control groups appear balanced, for example, randomization of households in the same geographic area may produce intervention and control arms with the same age distributions, hygiene habits, and health profiles. As summarized in Table 9, of the 11 studies, only 50% (9/18) reported controlling for at least 1 potential confounding factor. Although masking (also known as blinding) can be difficult to implement in hygiene studies because subjects, observers, and interviewers are usually aware of the intervention status, a few studies (2/18) were able to employ masking to reduce knowledge of the intervention. Masking can reduce biases associated with knowledge of intervention, including changes in behaviors, practices, and data collection methods.

For intervention studies, disregarding clustered sample design may cause bias. For example, a handwashing program in a day care center may affect a child's risk of disease through its individual-level effect (the effect of handwashing of a child on his or her own risk of disease) and through its group-level effect (the effect of center-wide handwashing on risk of disease, even if the child is not following the handwashing program). Clustered interventions must take into account the grouped data structure in subsequent analyses or must analyze data at the

Table 9. Methodologic considerations for the 11 intervention studies evaluating the impact of hand hygiene education or handwashing on reductions in respiratory and gastrointestinal illnesses

Percentage randomized	Percentage adjusted for confounding	Percentage masked	Percentage controlled for clustering*
60	50	10	50

*These studies either controlled statistically for clustered units or the unit of analysis reflected the unit of measurement.

same level at which it was collected. If the group or cluster is not controlled for, through specialized techniques such as generalized estimating equations, or analyzed at the group unit of measurement (average classroom illness rate), the investigator risks making a type I error (eg, falsely concluding that the effect of the intervention is significant, when there is no significant difference). Although most handwashing studies employ clustered data structures, use of clustered data statistical techniques have only become more prevalent since 2000.

THE EFFECTIVENESS OF SOAP-BASED HAND HYGIENE PROCEDURES AND ABHS

In the section above, which describes the development of a risk-based approach to home hygiene, we evaluated how pathogens are introduced into the home and the chain of events that can lead to healthy household members becoming infected. An assessment of the microbiologic data related to each stage of the infection transmission cycle suggests that the critical control points for preventing the spread of infection in the home are the hands, hand contact surfaces, food contact surfaces, and cleaning cloths and utensils. Intervention at the appropriate time (eg, during raw food handling, rather than as part of daily routine cleaning) is an equally fundamental part of a risk-based approach to hygiene. In practice, pathogens may be transmitted by more than one route, and it is impossible to achieve 100% hand hygiene compliance. Therefore, interventions to reduce ID transmission in the home must be multifaceted.

Key to preventing infection transmission via the hands (and other surfaces) is the application of effective hygiene procedures. Because the evidence reviewed in the earlier sections shows that the “infectious dose” for many common pathogens such as campylobacter, norovirus, and rhinovirus can be very small (1-500 particles or cells), intuitively one must argue that, in situations in which there is significant risk, the aim should be to get rid of as many organisms as possible from critical surfaces. Organisms can be removed from hands and other surfaces by the following:

- physical removal using soap or detergent-based cleaning; or
- microbes can be killed in situ by applying a disinfectant or sanitizer.

In principle, handwashing using soap or detergent and water mechanically dislodge organisms, but, to be effective, it must be applied in conjunction with a rubbing process that maximizes release of microbes from the skin and a rinsing process that washes the organisms off the hands. Although elimination of transient contamination from the hands by the application of a hygiene procedure is plausible, the evidence considered below suggests that, in practice, procedures vary considerably in the extent to which they achieve this. In this section, data on the efficacy of hand hygiene procedures are summarized. A range of test methods has been used to measure the efficacy of hand hygiene products and procedures. Although these methodologies yield valuable data, the results can vary considerably depending on the method used. In 2004, Sickbert-Bennet et al¹⁶⁹ produced a study, based on published literature and their own data, which indicated that factors that affect efficacy measurements are as follows: use of experimental contamination versus normal flora, application method of test organism, type of hand hygiene agent, concentration of active ingredient, volume, duration of contact and application method of the agent, and study method (in vivo panel test vs in vitro suspension test). Interpretation of data is made difficult by failure to compare multiple agents in the same study; because of these limitations, comparisons of results from different studies must be interpreted with care.

Efficacy of handwashing using soap and water

In vivo “panel test” studies of the effectiveness of handwashing. In Europe, the efficacy of handwashing is established by panel tests that determine the reduction in the number of organisms released from artificially contaminated hands. The test applicable to handwash products is the Committee European Normalisation Hygienic Handwash Test EN1499.¹⁷⁰ In this test, *E coli* is inoculated onto the hands and dried. The handwash product is applied to the hands with a rubbing action for either 30 seconds or 1 minute. The residual number of bacteria present on the hands is assessed pre- and postwash by a rinse sampling process and the log reduction determined. To make a claim that a product is a hygienic handwash, it must produce a log reduction in release of *E coli* from the hands at least equivalent to that produced by a reference soft soap product (mean, 2.76 log in 1 minute; range, 2.02-4.27). In the United States, handwashing is evaluated by a similar panel test using *Serratia marcescens* as

the test organism. The test applicable to consumer handwash products is the American Society for Testing Materials (ASTM) Standard Method for evaluation of Healthcare Handwash Formulations E1174.¹⁷¹ The product, when evaluated by this method, must produce a 2-log reduction after 5 minutes.

A range of studies, based on these methodologies, has been carried out to determine the efficacy of handwashing, and are reviewed by Boyce and Pittet,¹⁷² Kampf and Kramer,¹⁷³ and Sickbert-Bennet et al.¹⁶⁹ From their assessment, Kampf and Kramer estimated that handwashing produced a mean reduction of up to 2.4 log within 1 minute. Data from individual studies are summarized in Table 10 and suggest that, for *E coli*, the greatest reduction is achieved within the first 30 seconds, ranging from 0.6 to 1.1 log after 15 seconds to 1.8 to 2.8 log after 30 seconds. Extending the washing time to 1 minute produces a reduction of 2.6 to 3.23 log, but increasing the process for more than 1 minute does not appear to gain any additional reduction. Relatively few data are available on the effectiveness of handwashing in removal of viruses, but the available data (Table 10) suggest that handwashing may be less effective for viruses compared with bacteria.

Although panel test data suggest that handwashing efficacy is similar across a range of bacterial species, some field-based studies suggest that efficacy can vary quite significantly. In some cases, organisms can be attached to the hands too firmly and may not be removed by handwashing. A study of the spread of Salmonella and campylobacter from contaminated chickens via hands during handling and preparation in a kitchen¹⁷⁶ showed that, although campylobacter were efficiently released from the hands by a 30-second rub and rinse process, a 2-minute process was necessary to eliminate Salmonella. The hand rinsing process is also important; Cogan et al⁸⁶ showed that, following preparation of Salmonella and campylobacter-contaminated chickens in domestic kitchens, 15.3% of hands and hand and food contact surfaces still showed evidence of contamination even after participants had carried out a washing-up routine with detergent and hot water and then used a cloth to wipe surfaces. Sites contaminated most frequently were hands (20%); dishcloths, utensils, and tap handles (25%); and sink surrounds (30%). These results were confirmed in further studies^{176,177} in which, after cleaning up with a typical routine involving a bowl of hot soapy water and a cloth, although isolation rates from hands of participants were 5% (1/20) for campylobacter, 45% (9/20) of participants still had Salmonella on their hands, and, on 3 occasions, counts recovered were $>10^3$ colony-forming units. In a further study in which participants cleaned up in the same way but then rinsed their hands under running water for 10

Table 10. Effect of handwashing on transient hand flora*

Microorganism	Duration of handwash	Mean log reduction
<i>E coli</i>	10 seconds	0.5
	15 seconds	0.6-1.1
	30 seconds	1.37-3.0
	1 minutes	2.6-3.2
	2 minutes	3.27
<i>S marcescens</i>	10 seconds	1.87
<i>S aureus</i>	30 seconds	0.5-3.0
<i>P aeruginosa</i>	30 seconds	2.0-3.0
<i>C difficile</i>	10 seconds	2.0-2.4
Poliovirus	30 seconds	1.9
Rotavirus	10 seconds	0.14
	30 seconds	1.17-1.19
Bacteriophage MS2	10 seconds	1.82

*From Kampf and Kramer,¹⁷³ Sickbert-Bennet et al,¹⁷⁴ and Schurmann and Eggers.¹⁷⁵

seconds, no samples were positive for campylobacter. However, 15% (3/20) still had low numbers of Salmonella isolated from their hands. Larson et al showed that the quantity of soap (1 mL and 3 mL) used can also have an impact on the microbial reduction achieved by handwashing.¹⁷⁸

Bidawid et al^{165,166} studied the impact of handwashing in preventing transfer of HAV and FCV from artificially contaminated finger pads to pieces of lettuce (Table 11). Touching the lettuce for 10 seconds resulted in transfer of 9.2% and 18%, respectively, of the virus. When finger pads were washed before the lettuce was touched, the amount of virus transferred was reduced to 0.39% and 0.4%, respectively. Amounts of HAV and FCV remaining on treated finger pads were 6.5% and 7%, respectively. Surprisingly, virus transfer to lettuce when the finger pads were rinsed with water alone was between 0% and 0.3%, depending on the volume of water used for rinsing.

Barker et al showed that a thorough 1-minute handwash with soap was sufficient to eliminate norovirus from fecally contaminated hands to levels that gave negative reverse-transcription polymerase chain reaction assays.⁸⁹ However, Schurmann and Eggers¹⁷⁵ concluded that enteric viruses, particularly poliovirus, may be more strongly bound to the skin and that the inclusion of an abrasive substance in handwash preparations is needed to achieve effective removal. Handwashing was also found to be ineffective in eliminating adenovirus from hands of a physician and patients.¹⁷⁹

For handwashing, a hand-rubbing time of 15 seconds with soap is generally recommended, although the data in Table 10 indicate that 30 seconds to 1 minute is needed to achieve the optimum of 2- to 3-log reduction. In practice, it is doubtful whether people comply with even a 15-second handwash, although there are few data to confirm this. A study of 224 healthy

Table 11. Efficacy of handwashing and alcohol-based hand sanitizers in preventing transfer of hepatitis A and feline calicivirus from fingertips to lettuce

	Hepatitis A		Feline calicivirus	
	Particles transferred to lettuce, %	Particles remaining on hands, %	Particles transferred to lettuce, %	Particles remaining on hands, %
No treatment	9.2		18	
Handwashing	0.39	6.5	0.4	7
62% Ethanol, 20 seconds	0.64	64	2.1	13
75% Ethanol, 20 seconds	0.46	24	1.2	17

homemakers in New York¹⁸⁰ showed that a single handwash had little impact, with mean log counts of 5.72 before compared with 5.69 after handwashing. Another study with 52 office workers and students showed a mean log prewash count of 4.81 compared with 5.07 postwash.¹⁸¹ Kampf and Kramer¹⁷³ also reviewed studies from health care settings in which increased bacterial counts were found on the hands after handwashing, and handwashing failed to prevent transfer of bacteria from hands to surfaces. Although there are no data available to confirm this, increases in contamination may result from sweating induced by hot water, which flushes resident bacteria from the sweat glands onto the hand surface or aids detachment of bacteria attached to skin scales.

It is important to bear in mind that, although soap and water removes contamination from the hands, soap itself has a limited antimicrobial effect, which means that contamination will be transferred to the sink. Hospital studies show that *Pseudomonas aeruginosa* and *Burkholderia cepacia*¹⁸² can form reservoirs of contamination in sink waste pipes and can be a source of infection at times when splashes of contaminated water come in contact with hands. Mermel et al reported that hands of HCWs became recontaminated from faucet handles during a *Shigella* outbreak.¹⁸³ Soap bars also have the potential to spread contamination from person to person via the hands.⁸⁸

Efficacy of ABHS

ABHS are formulations that contain either ethanol 1-propanol or 2-propanol or a combination of these products. Their antimicrobial activity is attributed to their ability to denature proteins. Although products containing 60% to 95% alcohol are most effective, higher concentrations are less effective because proteins are not easily denatured in the absence of water. A range of in vivo and in vitro studies have been carried out to determine the effectiveness of ABHS and are reviewed by Boyce and Pittet,¹⁷² Kampf and Kramer,¹⁷³ and Sickbert-Bennet et al.¹⁶⁹

In vivo panel testing of ABHS. In Europe, the efficacy of ABHS is established by panel tests that determine the reduction in the number of organisms released from artificially contaminated hands. The test applicable to ABHS is the Committee European Normalisation Hygienic Handrub Test EN1500.¹⁸⁴ In this test, *E coli* is inoculated onto the hands and dried. The sanitizer is applied to the hands with a rubbing action for a specified period. The residual number of bacteria present on hands is assessed pre- and post-treatment by a rinse-sampling process and the log reduction determined. To claim that a product is a hygienic handrub, it must produce a log reduction at least equivalent to that produced by a reference product containing 60% vol/vol 2-propanol (mean, 4.24 log in 1 minute; range, 3.17-6.46).

In vivo panel testing against bacterial strains. Data from in vivo panel tests, summarized in Table 12, indicate that ABHS show good and rapid activity against bacterial stains such as *E coli* and *S aureus*. Efficacy is at least as good, if not better, than that achieved by handwashing with soap (Table 10); log reductions obtained after a 30-second contact period were of the order of 3.4 to 3.7 or more compared with 1.8 to 2.8 for a 30-second handwashing process. Boyce and Pittet¹⁷² conclude that, typically, log reductions of the release of test bacteria from artificially contaminated hands average 3.5 log after 30 seconds and 4.0 to 5.0 log after 1 minute.

Paulson et al¹⁸⁵ compared the efficacy of ABHS containing 62% ethanol (contact time 5 minutes) with handwashing against *S marcescens*, which showed that handwashing (20 seconds rubbing followed by 30 seconds rinsing) produced a log reduction of 2.29 compared with 3.83 for the ABHS. Hammond et al¹⁸⁶ recorded a 2.84-log reduction for 62% ethanol against *S marcescens* in 10 seconds using the ASTM method. Sickbert-Bennet et al,¹⁷⁴ however, showed that exposure of *S marcescens* to 60% to 62% ethanol for 10 seconds produced only a 1.15- to 1.55-log reduction compared with 1.87-log reduction for handwashing for 10 seconds, when tested by the ASTM 1147 method.

Table 12. Efficacy of alcohol-based hand sanitizers in reducing the release of bacteria from artificially contaminated hands

Agent	Concentration (%)	Test bacterium	Mean log reduction exposure time (min)		
			0.5	1.0	2.0
1-propanol	100	<i>E coli</i>	-	5.8	-
	60		-	5.5	-
	50		3.7	4.7	4.9
	40		-	4.3	-
2-propanol	70	<i>E coli</i>	-	4.9	-
			3.5	-	-
	60	<i>E coli</i>	-	4.0-4.4	-
		<i>S marcescens</i>	-	4.1	-
Ethanol	50	<i>E coli</i>	3.4	3.9	4.4
	80	<i>E coli</i>	-	4.0	-
	70		3.4-3.6	3.8-4.3	4.5-5.1
		<i>S aureus</i>	3.7	-	-
	60	<i>E coli</i>	-	3.8	-

Leischner et al¹⁸⁷ carried out in vivo tests that showed that alcohol gels were significantly less effective against *C difficile* spores (1.68- to 1.94-log reduction) compared with handwashing with chlorhexidine soap (2.46-log reduction). Residual spores were readily transferred by handshaking following ABHS use.¹⁸⁷ The reduction in spore counts is higher than expected in view of their known resistance to alcohol and may result from the friction associated with application of the gel rather than a bactericidal action; Kampf and Kramer¹⁷³ state that water alone can produce a reduction of 0.5 to 2.8 log within 1 minute for *E coli*.

Using the standard ASTM 1174 method, Sickbert-Bennet et al evaluated the effect of exposure time and volume of product used on the efficacy of 62% ethanol.¹⁶⁹ They showed that the use of 7 g of the ABHS produced a higher log reduction compared with 3 g (2.7- to 3.8-log reduction compared with 1.0- to 1.8-log reduction). Rubbing the hands until dry (3-12 minutes) was more effective compared with a 10-second application (1.0- to 1.6-log reduction compared with 0.6- to 1.1-log reduction).

Two recent field studies indicate that an ABHS is equally or slightly more effective than handwashing in reducing bacterial contamination on hands. Davis et al¹⁹ compared the reduction of bacterial counts on hands using soap and water or a 62% ethanol-based hand sanitizer (contact time 30 seconds) after animal handling at a US livestock event. There was no significant difference in the distribution of log reductions obtained using ABHS compared with handwashing; log reductions in total count ranged from -1.4 to 1.4 and -3.0 to 3.5 for total coliforms. Traub-Dargatz et al carried out a study at 2 clinics in Canada to evaluate the efficacy

of handwashing compared with use of ABHS (62% ethanol, contact time 30-60 seconds) on veterinary staff performing routine equine physical examinations.¹⁸⁸ Mean bacterial load on hands increased by 0.36 and 0.91 log (for the 2 clinics, respectively) as a result of handling the animals, whereas the mean log reduction produced by handwashing with soap was less than 0.6, compared with 1.29 and 1.44 log (for the 2 clinics, respectively) produced by ABHS.

In vivo panel testing against viral strains. A number of in vivo studies have been carried out to determine the efficacy of ABHS in reducing the release of viruses from hands. Test methods were variants of the method of Ansari et al¹⁸⁹ or the ASTM E1174 method,¹⁷¹ in which the virus is applied to the fingertips and the efficacy of the product in reducing the numbers of viral particles recoverable from the hands determined. The residual number of viral particles present on the hands is assessed pre- and posttreatment and the log reduction determined. Data collated by Boyce and Pittet¹⁷² (Table 13) indicate that ethanol at 60% to 80% produces a 0.8- to >3-log reduction against a range of viruses, the extent of the reduction depending on the viral strain, the nature and concentration of the alcohol, and contact time.

Data indicate that activity of ABHS against viral strains is less than against bacterial strains and that ethanol has greater activity against viruses than 2-propanol. However, all of the strains referred to in Table 13 are nonenveloped viruses, which are known to be more resistant to disinfectants than enveloped viruses. As far as hand hygiene in the home and community is concerned, however, this is key because many of the viral strains responsible for hygiene-related ID commonly occurring in community settings (rotavirus, norovirus, rhinovirus, and adenovirus) are nonenveloped. That having been said, the data suggest that, although nonenveloped viruses such as HAV and enteroviruses (eg, poliovirus) require 70% to 80% alcohol to be reliably inactivated, studies by Sattar et al¹⁹⁴ suggest that 60% ethanol was sufficient to reduce the titers of rotavirus, adenovirus, and rhinovirus by >3 log within a 10-second contact period. Data indicate that FCV may also be relatively susceptible to alcohols compared with other nonenveloped viruses, although sensitivity depends on the type and concentration of alcohol. Using an in vivo test based on the ASTM 1838-02 method, Gehrke et al¹⁹⁰ showed that 70% ethanol was the most effective agent against FCV with a log reduction of 3.78 compared with 70% 1-propanol (log reduction, 3.58) and 70% 2-propanol (log reduction, 2.15) (exposure time 30 seconds). However, a more recent study by Kampf et al¹⁹¹ suggested a log reduction after 30 seconds of only 2.66 and 1.53 for 70% ethanol and 70% 1-propanol, respectively.

Table 13. Efficacy alcohol-based hand sanitizers in reducing the release of test bacteria from artificially contaminated hands

Agent	Test strain	Contact time	Outcome: log reduction		Reference
			Product	Soap and water	
Ethanol 70%	Hepatitis A	10 seconds	0.89 [†]	0.66	Mbithi et al ¹⁹⁶
	Polio		1.34 [†]	0.97	
Ethanol 80%	Poliovirus	30 seconds	0.4	2.1	Davies et al ¹⁹²
Ethanol 70%	Rotavirus	10 seconds	2.4	0.89	Ansari et al ¹⁸⁹
Ethanol 80%	Polio	10 seconds	1.6		Steinman et al ¹⁹³
2-propanol 70%			0.8		
1-propanol 70%			0.8		
Ethanol 60%	Rotavirus	10 seconds	>3		Sattar et al ¹⁹⁴
	Adenovirus		>3		
	Rhinovirus		>3		
2-propanol 70%	Bovine rotavirus	30 seconds	3.1	1.2	Bellamy et al ¹⁹⁵
Ethanol 70%			2.9		
Ethanol 70%	Feline calicivirus	30 seconds	3.78		Gehrke et al ¹⁹⁰
1-propanol 70%			3.58		
2-propanol 70%			2.15		
Ethanol 70%			2.66		
1-propanol 70%			1.53		Kampf et al ¹⁹¹

*From Boyce and Pittet.¹⁷²[†]Sufficient to prevent transfer of virus from fingers to another surface.

In a number of these studies, handwashing with soap was also investigated. These studies^{175,189,196} showed that the action of ABHS against HAV, polio, and rotavirus was significantly better than that achieved by handwashing with soap. However, in the test model used by Ansari et al¹⁸⁹ and Mbithi et al,¹⁹⁶ inoculated fingertips are exposed to soap solution or ABHS by inverting them over a vial containing the product. In practice, handwashing involving rubbing and rinsing is likely to remove larger numbers of organisms from hands. In a further experiment, Ansari et al¹¹⁵ also demonstrated that 2-propanol (70%) was more effective (98.9% reduction after 10 seconds) than liquid soap (77% reduction) against rotavirus.

Mbithi et al showed that the log reduction of polio and HAV virus (0.89-1.34) by application of 70% ethanol was sufficient to prevent transfer to another surface via the fingertips.¹⁹⁶ Using similar methodology, Bidauid et al^{65,66} studied the impact of ethanol hand sanitizers in preventing transfer of HAV and FCV from artificially contaminated finger pads to pieces of lettuce. Results (Table 11) show that touching the lettuce for 10 seconds resulted in transfer of 9.2% and 18%, respectively, of the virus. When finger pads were treated with 62% ethanol or 75% ethanol (contact time 20 seconds) before the lettuce was touched, the amount of virus transferred was reduced to 0.64% and 0.46%, respectively, for HAV and 2.1% and 1.2%, respectively, for FCV. Although both 62% and 75% alcohol produced significant reductions in virus transfer, significant amounts of virus were found to remain on

treated finger pads. In all cases, treatment with ethanol was less effective than handwashing.

Kampf and Kramer¹⁷² and Boyce and Pittet¹⁷³ suggest that, to achieve satisfactory activity against nonenveloped viruses, higher alcohol concentrations and extended contact times are needed. Absolute ethanol reduced viral release from hands by 3.2 log, 80% ethanol by 2.2 log, and absolute 1-propanol by 2.4 log¹⁹⁷ but with a contact time of 10 minutes. Schurmann and Eggers¹⁷⁵ concluded that high alcohol-concentration products are effective against enteroviruses only under favorable conditions (large disinfectant/virus volume ratio, low protein load). Other studies also demonstrate superior activity of high ethanol concentrations against nonenveloped viruses such as polio, HAV, and adenovirus.^{198,199}

In vitro testing against bacteria, viruses, and fungi. Whereas in vivo tests can be used to indicate the efficacy of products under use conditions, in vitro suspension tests are used to establish whether efficacy extends to a broad range of organisms.

In vitro testing bacterial and fungal strains. Alcohols have excellent and rapid activity against gram-positive and gram-negative vegetative bacteria and fungi when tested in vitro.^{172,173} A study by Fendler et al²⁰⁰ (Table 14) shows the efficacy of an ABHS containing 62% ethyl alcohol against a range of bacterial and fungal species, giving 4- to 6-log reduction in 15 to 30 seconds.

In vitro testing against viral strains. Data, as reviewed by Boyce and Pittet,¹⁷² confirm that enveloped viruses

Table 14. In vitro tests to determine the efficacy of 62% ethanol against bacterial and fungal strains*

Microorganism type	Species	Log ₁₀ reduction
Gram-positive and gram-negative bacteria	<i>Clostridium difficile</i> ; <i>Corynebacterium diphtheriae</i> ; <i>Enterococcus faecalis</i> (vancomycin-resistant); <i>Enterococcus faecium</i> (vancomycin-resistant); <i>Listeria monocytogenes</i> ; <i>Staphylococcus aureus</i> (methicillin-resistant); <i>Staphylococcus epidermis</i> ; <i>Streptococcus pneumoniae</i> ; <i>Staphylococcus progenies</i> ; <i>Pseudomonas aeruginosa</i> ; <i>Escherichia coli</i> (including O157:H7); <i>Salmonella enteritidis</i> ; <i>Salmonella typhimurium</i> ; <i>Serratia marcescens</i> ; <i>Shigella dysenteriae</i> ; <i>Shigella sonne</i>	>4.20 to >5.00
Fungi	<i>Aspergillus flavus</i> ; <i>Aspergillus niger</i> ; <i>Candida albicans</i> ; <i>Candida tropicalis</i> ; <i>Epidermophyton floccosum</i> ; <i>Penicillium citrinum</i> ; <i>Trichophyton mentagrophytes</i>	>3.92 to >6.42

*From Fendler et al.²⁰⁰

Table 15. In vitro tests to determine the efficacy of alcohol-based hand sanitizers against viruses

Type	Species	Product	Contact time	Log reduction	Reference
Enveloped viruses	Herpes type A; influenza A ₂ . Parainfluenza types 2 and 3; hepatitis A; influenza A ₂	Ethanol 62%	30 seconds	>5	Hammond et al ¹⁸⁶
		Ethanol 62%	30 seconds	>4.1 to >5.0	Fendler et al ²⁰⁰
Nonenveloped viruses	Adenovirus type 2; rhinovirus types 14 and 37; coxsackie B ₃ . Rhinovirus type 16	Ethanol 62%	30 seconds	1.25 to 2.75	Fendler et al ²⁰⁰
		Ethanol 62%	30 seconds	>4.25	Hammond et al ¹⁸⁶ Fendler et al ²⁰⁰
	Feline calicivirus (surrogate for norovirus)	1-propanol 50%-70%	30 seconds	>4	Gehrke et al ¹⁹⁰
		Ethanol 50%	30 seconds	2.19	
			1 minute	3.65	
		Ethanol 70%	30 seconds	2.19	
			1 minute	>3.8	
		2-propanol 50%	30 seconds	2.31	
		1 minute	3.22		
		2-propanol 70%	30 seconds	2.31	
		1 minute	2.35		
	SARS coronavirus	Ethanol 85%-95%	30 seconds	>4.25	Rabenau et al ²⁰²

such as herpes, influenza, PIV, and RSV are very susceptible to alcohols. Data from individual studies (Table 15) suggest that activity against enveloped viruses is equivalent to that against bacterial strains. However, in agreement with in vivo data, alcohols tend to be less effective against nonenveloped viruses, although this is not the case for all strains. Fendler et al²⁰⁰ confirmed good activity for ethanol (62%) against PIV and herpes viruses (>4-log reduction in 30 seconds) and some, but relatively less, activity against the nonenveloped rhinovirus, coxsackie virus, adenovirus, and HAV (1- to 3-log reduction in 30 seconds). Hammond et al¹⁸⁶ showed >5-log reduction against herpes and influenza virus but also >4.25-log reduction against rhinovirus type 16. There are no data on efficacy against rotavirus in vitro.

In vitro tests suggest that alcohols are relatively effective against FCV, although Gehrke et al¹⁹⁰ (Table 15) found that 1-propanol was more effective than 2-propanol and ethanol. It was also found that these alcohols were less effective against FCV at 80% than at 50% and 70%. At this concentration (80%), 1-propanol,

2-propanol, and ethanol produced log reductions of only 1.9, 1.35, and 2.16, respectively. By contrast, Duijzer et al²⁰¹ showed that 70% ethanol produced less than a 2-log reduction for FCV after 8 minutes and a 3-log reduction after 30 minutes.

These data are confirmed by a further study (McNEIL-PPC unpublished) using in vitro suspension test methods as used to generate data in Table 15. The data (Table 16) show that 62% ethanol gave a 3- to 6-log reduction in 30 seconds against a range of non-enveloped viruses including not only RSV, PIV, and influenza A and B but also against some strains of rhinovirus and echovirus.

Efficacy of ABHS under conditions of soiling. Alcohols are considered inappropriate when hands are visibly dirty or soiled because they fail to remove soiling. However, in a number of in vitro studies, in which the efficacy of ABHS was determined in the presence and absence of soil (10% fetal calf serum or 0.3% bovine serum albumin), soil produced little or no loss of efficacy.^{198,202} Larson and Bobo showed that, in the presence of small amounts of protein material (eg, blood),

Table 16. In vitro tests to determine the efficacy of alcohol hand gel containing 62% ethanol: contact time 30 seconds

Virus	Log reduction
Adenovirus 5	0.33
Adenovirus 6	0.33
Adenovirus 7	0.27
Adenovirus 8	0.66
Coronavirus 229E	2.83
Coronavirus OC43	2.00
Echovirus 9	5.00
Echovirus 11	4.83
Influenza A2	6.0
Influenza B	6.0
Parainfluenza 1 (sendai)	6.0
Parainfluenza 4b	3.0
Respiratory syncytial virus	3.17
Rhinovirus 18	3.83
Rhinovirus 2	5.0
Rhinovirus 14	6.0

ethanol and 2-propanol were more effective than soap in reducing bacterial counts on hands.²⁰⁵ Using the ASTM 1174 method, Sickbert-Bennet et al¹⁶⁹ showed that applying protein to hands did not produce any significant reduction in efficacy of ABHS or handwashing but produced a modest but significant increase; log reductions for handwashing were 1.18 to 1.39 and 1.56 to 1.87 in the absence and presence of protein, respectively. Log reductions for ABHS were 0.18 to 1.07 and 1.35 to 1.55 in the absence and presence of protein, respectively.

Assessing the efficacy of handwashing and ABHS by Quantitative Microbiologic Risk Assessment

One of the problems in developing hygiene promotion policies is the lack of quantitative data on the relative health impact of different hygiene interventions. Although intervention studies yield quantitative data on health impact, as discussed in section 4.2, the reliability of these estimates is difficult to confirm. By contrast, in vivo and in vitro tests are more economic to perform and can be used to determine relative efficacy of different procedures but give no assessment of how the contamination reduction on hands correlates with health impact. In an attempt to overcome these problems, Haas et al have applied the technique of Quantitative Microbial Risk Assessment (QMRA) to estimate the relative health benefits resulting from use of different hygiene procedures.²⁰⁴ This approach involves using microbiologic data from the published literature related to each stage of the infection transmission cycle to calculate infection risk.

In a recent study,²⁰⁵ these investigators developed a model for studying the effect of hand contact with ground beef during food preparation, which was used to study the impact of handwashing and use of ABHS in preventing subsequent transference from the hands to the mouth compared with no handwashing. Pathogenic *E coli* and *E coli* O157:H7 were selected for this study because it is known from other investigations²⁰⁶ that handling ground beef during home food preparation poses a risk of infection with *E coli*. To perform the risk assessment, data on the density of pathogens in ground beef, transference from beef to hands, removal by handwashing or ABHS, rate of transfer from hand to mouth, and infectivity of ingested pathogens were obtained from the literature and, after screening for data quality, were used to develop probability distributions. For assessing log reductions produced by hand hygiene procedures, only in vivo panel testing data were considered. The median log reduction used in these calculations was 0.3 (range, 0.2-3.0) for handwashing and 4.3 (range, 2.6-5.8) for ABHS.

Table 17 shows the estimates of the infection risk from handling raw beef, as obtained from the analysis. The authors note that these risks are conditional in the sense that they quantify the risk to an individual who has handled ground beef and who engages in hand-to-mouth activity. The probability that an individual will engage in such behavior is not known, and, therefore, a direct comparison with actual disease rates cannot be made. However, with some plausible assumptions, it was assessed that, assuming that there are 100 million individuals in the United States, each of whom handles ground beef once per month, this results in 1.2×10^9 contacts per year. Assuming that 10% of these individuals contact hand to mouth after handling ground beef, this amounts to 1.2×10^8 incidents per year. For *E coli* O157:H7, using the median risk, this would result in an estimate ranging from 0.014 infections per year if all individuals washed their hands with soap following contact with ground beef to 0.7 infections per year if no handwashing is done. This would equate to a 98% median risk reduction for handwashing compared with no handwashing. If an ABHS was used, this would result in an estimate of 0.00005 infections per year if all individuals used ABHS following contact with ground beef. This would equate to a 99.9996% median risk reduction for use of ABHS compared with handwashing.

This study follows an earlier study by Haas et al²⁰⁷ to calculate risks associated with hand-to-mouth transfer after diaper changing of a baby infected with *Shigella*. Based on this model, it was calculated that the probability of acquiring infection was between 24 of 100 and 91 of 100 for those who used handwashing with soap after changing diapers. This was based on panel test data

Table 17. Mean and median risks of infection from handling raw beef and subsequent hand-to-mouth contact with or without handwashing intervention

Active	<i>Escherichia coli</i>			<i>Escherichia coli</i> 0157		
	No handwashing	Handwashing	Use of alcohol hand rub	No handwashing	Handwashing	Use of alcohol hand rub
Mean	8.24×10^5	2.61×10^6	5.46×10^8	1.39×10^2	1.25×10^2	1.15×10^2
Median	9.57×10^8	1.86×10^9	5.36×10^{12}	5.98×10^9	1.18×10^{10}	3.71×10^{13}
Standard deviation	9.00×10^4	3.18×10^5	1.33×10^6	7.79×10^2	7.52×10^2	7.26×10^2

indicating a mean log reduction of *S marcescens* on hands because of handwashing of 2.56. The authors calculated that, by using a hand hygiene formulation that increased the log reduction to 2.91, the infection risk would be reduced to between 15 of 100 and 90 of 100.

Haas et al²⁰⁵ conclude that quantitative microbial and ID risk models offer a useful tool to assess the relative extent to which different hygiene procedures can impact on ID risks. They concede, however, that, although risk modeling represents a promising approach, there are limitations to most models because of the multifactorial nature of infection transmission, the dynamic environment in which transmission takes place, and the paucity of data to specify model parameters.

Intervention studies of the effectiveness of handwashing and ABHS

In an earlier section, we evaluated intervention study data to assess the strength of the causal link between hand hygiene and ID transmission. In this section, we use these data to evaluate the effectiveness of handwashing as a hygiene measure and in relation to the effectiveness of using ABHS as an adjunct or an alternative to handwashing.

Despite the methodologic limitations, the collective weight of evidence from intervention and microbiologic studies described earlier suggests that handwashing with soap can have a significant impact in reducing the incidence of GI and RT infection. The data, however, show that the health impact from handwashing promotion varies significantly according to the setting and outcome. Statistically significant reductions ranged from 48% to 57% for GI illness and 20% to 51% for RT illness. Although all studies were carried out in settings such as day care centers and schools, we believe that the modes of transmission in these settings and the relative rates of transmission of RT and GI infections are likely to reflect those occurring in the home.

In 2004, Meadows and Le Saux published a review of the effect of rinse-free hand sanitizers in elementary schools over a 20-year period.²⁰⁸ They concluded, however, that the data were of poor quality and that more rigorous intervention trials are needed. In a more recent study, Aiello et al examined the

epidemiologic evidence for a relationship between waterless hand sanitizers and infections in the community setting over several decades.¹⁵⁴ In Table 18, we present the studies that specifically examined ABHS. Only studies with an effect estimate and 95% CI are presented. The type and content of the ABHS varied across studies, for example, one study reported the use of a 60% isopropyl alcohol rinse and another study utilized an alcohol-based foam sanitizer. However, most studies used alcohol-based gels or other alcohol-based emollients. The alcohol content included ethanol and 2-propanol at concentrations ranging from 60% to 90%.

Of the 8 intervention studies, 7 were conducted in the United States (88%, 7/8) and 1 in Finland (13%). Most were conducted in child day care centers, elementary schools, or universities (88%, 7/8), and one was conducted in the household (13%, 1/8). Outcomes included GI-related illnesses/symptoms and/or upper RT-related illnesses/symptoms examined as separate outcomes or in combination with other infection-related symptoms as part of a school absence-related definition of "infectious-illness." Of the 8 studies, 88% (7/8) reported significant results for at least one age group or outcome. The effect was stronger in younger compared with older age groups for studies providing age stratified data.

The reduction in GI illness ranged from 0% to 59% for the 4 intervention studies that examined GI illnesses as separate outcomes.^{209-211,215} Of these, all but one showed statistically significant reductions.²¹⁰ The study by Uhari et al showed a significant reduction in GI illness only among children ≤ 3 years of age.²¹¹ All but one of these studies was conducted in child care settings.²¹⁵ When evaluated separately, reductions in GI illness appeared more robust compared with the findings for upper RT illness.

For upper RT illness, the reduction in infectious illness/symptoms ranged from -6% to 26%. Only 2 of the 5 studies (44%) examining upper RT illness as a main outcome reported a statistically significant reduction. Uhari et al reported a 13% reduction in RT illnesses among children ≤ 3 years of age, but no significant effect in older children.²¹¹ White et al reported a 20% reduction in upper RT illness among students using ABHS in

Table 18. Effectiveness of alcohol-based hand sanitizers on infectious illnesses in the community setting

Intervention	Control	Setting, country	Outcome measured	Result, % reduction (95% CI)	Statistical significance	Reference
HEP HP: HW + use of ABHS as supplement	No HEP or HP	Child care, United States	Enteric disease Runny nose	29 (0.07-0.45) -5 (-0.16-0.05)	Enteric: Yes Runny nose: No	Butz et al ²⁰⁹
HEP HP: HW + use of ABHS where no alternative	No HEP or HP	Child care, United States	Diarrhea Respiratory	16 (-0.06-0.33) -6 (-0.21-0.06)	No	Kotch et al ²¹⁰
HEP HP: "intensified" handwashing, use of alcohol-based oily disinfectant plus other measures	No HEP or HP	Child care, Finland	Enteric disease Cold Any infectious illness	Age ≤3: 20 (0.09-0.30) Age >3: 0 (-0.22-0.18) Age ≤3: 13 (0.07-0.18) Age >3: 4 (-0.04-0.11) Age ≤3: 9 (0.05-0.13) Age >3: 8 (0.02-0.13)	Enteric ≤3: Yes Enteric >3: No Cold ≤3: Yes Cold >3: No Any ≤3: Yes Any >3: Yes	Uhari and Mottonen ²¹¹
No HEP HP: maintain normal handwashing, use of ABHS at specified times additionally also, eg, after sneezing	Maintain normal handwashing	Elementary school, United States	Illness-related absenteeism	20 (0.17-0.22)	Yes	Hammond et al ¹⁸⁶
HEP HP: normal HW + use of ABHS in classrooms	No HEP or HP	Elementary school, United States	Illness-related absenteeism	50 (0.38-0.59)	Yes	Guinan et al ²¹²
HEP HP: HW + regular use of ABHS as supplement	No HEP or HP	University, United States	Respiratory illness rates and absenteeism	26 (0.17-0.35)	Yes	White et al ²¹³
HEP HP: HW + regular use of ABHS as supplement	HEP	Elementary school, United States	Illness-related absenteeism	44 (0.16-0.62)	Yes	Morton and Schultz ²¹⁴
HEP HP: ABHS supplied for use in the home	No intervention	Home, United States	Gastrointestinal Respiratory	59 (0.10-0.81) 3 (-0.3-0.28)	Gastrointestinal: Yes Respiratory: No	Sandora et al ²¹⁵

Ages are in years.

HEP, hygiene education program, eg, chain of infection explained; HP, hygiene promotion, eg, promotion of handwashing and/or use of ABHS plus other measures; CI, confidence interval.

residence halls.²¹³ However, this study suffered from several methodologic shortcomings, including lack of control for clustered units, no randomization, no masking, and no monitoring of product use.

All but one of the intervention studies included a hygiene education component, but, in 7 of these studies, this was only provided in the intervention arm. The level of education varied widely, ranging from basic information on when to use the ABHS (ie, after sneezing and coughing, after use in the restroom, before lunch) to in-depth education programs²¹⁴ and biweekly

instructional material designed to educate families on hand hygiene and infection transmission.²¹⁵ In all studies, ABHS was promoted as a supplement to handwashing, or as an alternative to handwashing when soap was unavailable, and it is likely that the hygiene education would have had the effect of encouraging more frequent handwashing as well as use of ABHS. Although almost all studies indicated that hygiene education combined with promotion of ABHS can reduce the risks of GI or RT illness, only 2 studies allowed any assessment of the independent effect of the ABHS. Of these 2 studies,

the study by Hammond et al¹⁸⁶ did not provide any educational component to either arm, and the study by Morton and Schultz²¹⁴ provided education to both intervention and control arms. Both studies showed a significant reduction in illness-related absences (20% and 44%, respectively), but it is not clear whether the illnesses were predominantly GI or RT because these studies used a loose definition of absence-related illnesses.

Sandora et al²¹⁵ was the only study carried out in the household setting and, of all the studies, reported the highest reduction for GI illness. The trial involved 292 families with children enrolled in 26 child care centers. Intervention families received a supply of ABHS and biweekly hand hygiene educational materials for 5 months; control families received only materials promoting good nutrition. A total of 252 GI illnesses occurred during the study; 11% were secondary illnesses. The secondary GI illness rate was significantly lower (59%) in intervention families compared with control families (see Table 18). A total of 1802 RT illnesses occurred during the study; 25% were secondary illnesses. Although RT illness rates were not significantly different between groups, families with higher ABHS usage had marginally lower RT illness rate than those with less usage (19% reduction). Sandora et al²¹⁵ suggested that the difference may be due to heightened diligence associated with using ABHS after a GI-related incident compared with an RT incident, such as sneezing.

Overall, based on relatively limited data available, the results in Table 18 suggest that the impact of ABHS promotion, as part of a hygiene education and promotion program in reducing the incidence of GI infections in young children, is similar to that observed for promotion of handwashing with soap. Promotion of ABHS in this manner also produced some reduction in the incidence of RT infections, which was less than that associated with promotion of handwashing alone. Assessing whether there might be an added health benefit of using ABHS above and beyond the effect of hygiene education is hampered by the fact that most studies used hygiene education and ABHS in the intervention arm but did not provide an educational component to the control arm.

Several important methodologic issues were evident, although more recent studies have improved designs and conduct. In most studies, either parents or school personnel provided information on ID among children in the study populations. In all but one study,³⁴ the parents, participants, or personnel monitoring and reporting infections were not masked as to their own or their child's intervention status. Although masking of participants and interviewers to the intervention status is important, because it might influence reporting, it is often difficult to conduct masked hygiene interventions

and may not be ethical. Sandora et al determined that it was neither feasible nor ethical to mask subjects or interviewers because it is difficult to devise a formulation that could act as a "placebo" for ABHS, and using a placebo ABHS product might endanger the control group via inadequate hand hygiene.²¹⁵

In many of the ABHS studies, especially the recent ones, efforts were made to control for potential confounding factors. However, many of the studies did not collect information on baseline hand hygiene practices (nor methods and frequency of cleaning/disinfecting soiled/contaminated environmental surfaces in homes) as well as ABHS use. The studies also excluded participants who reported current ABHS use in the home. Furthermore, participants were asked to refrain from using ABHS in settings outside the home. These are all important design strategies minimizing bias associated with noncompliance or differential usage. Two of the 8 intervention studies failed to use systematic monitoring for hygiene practices, such as frequency of hand-sanitizing episodes, frequency of handwashing, or duration of handwashing.^{212,213} This is especially concerning because the study by Sandora et al suggests that the quantity of ABHS influences the risk of infection in a dose-response manner.²¹⁵ Moreover, if frequency of handwashing and ABHS use is not recorded, it is impossible to isolate the independent effects of ABHS from that of handwashing on infection rates. In these studies of ABHS use, surveillance measures included calculating use from monthly demand, total amount supplied, observation by research assistants, participant report, and reported use by primary caregivers in households.^{186,209,212,214,215}

THE HEALTH IMPACT OF HAND HYGIENE

Overall, the microbiologic data, together with the intervention study data (both those involving ABHS as well as those involving handwashing) as presented in this review, provide consistent evidence of a strong causal link between hygiene and the spread of infection in the home and community, and suggest that probably the single most important route for the spread of infection is the hands. If the data from intervention studies (summarized in Table 19) are an accurate reflection of the true picture, it is suggested that, for up to 60% of GI illnesses, the hands are the "sufficient," or a "component" (see earlier for definitions), cause of spread of infection. This correlates with microbiologic and other data reviewed in this report, which suggest that, although there is a tendency to assume that GI infections are mostly foodborne and result from inadequate cooking and inadequate storage of food, in reality, most GI infections in the home result from person-to-person spread or contamination of

Table 19. Summary of data from intervention studies on the health impact of hand hygiene

Type of infection	Area of study	Outcome of intervention-risk reduction			
		Handwashing with soap		ABHS	
		Range	No. of statistically significant studies (range)	Range	No. of statistically significant studies* (range)
Gastrointestinal	Developed countries only	-10%-57%	3/5 Studies (48%-57%)	0%-59%	3/4 Studies (20%-50%)
Respiratory	Developed and developing countries	5%-53%	2/6 Studies (20%-51%)	-6%-26%	2/4 Studies (13%-26%)

*Where at least one of the age groups showed a statistically significant result ($P < .05$).

ready-to-eat foods within the home, much of which involves the hands as the sufficient or a component cause. For RT illnesses, the intervention study data (summarized in Table 19) suggest that transmission via hands could be a sufficient or component cause of up to 50% of illnesses; whereas there has been a tendency to assume that the lower impact of hand hygiene on RT compared with GI infections is due to the fact that spread of RT pathogens is mainly airborne, the microbiologic and other data in this review correlate with the intervention data in suggesting that, for RT infections commonly circulating in the community, such as rhinovirus and RSV, the hands are the major route of spread.

Although up to 50% to 60% reduction in ID risk was observed in some intervention studies, in other studies the reduction was much less. This variability could well be due to methodologic issues but could also be due to other factors within and between study communities. One possibility is that it relates to differences in the range of pathogens with differing modes of spread prevalent in different study groups, which means that hand hygiene has greater impact in some intervention groups than others. Alternatively, the differences may reflect differing levels of hand hygiene compliance in different intervention groups. In some studies, the quality of the hygiene education, the manner in which the hygiene promotion was conducted, and the enthusiasm with which it was received may have given the intervention group a better understanding of what was required, with the result that they used better hygiene technique and were more likely to apply it at critical times. Although there are no intervention study data to confirm this, the microbiologic data together with the QMRA assessments suggest that even a relatively modest increase in log reduction on hands within a population could produce a significant increase in the health impact of a hand hygiene promotion campaign, which could, in turn, be achieved by addressing the issues in the next 2 sections.

Efficacy of the hand hygiene procedure

Although panel tests carried out under controlled conditions showed that handwashing can reduce the numbers of bacteria and some viruses on the hands by up to 2- to 3-log within 30 seconds to 1 minute, in practice it is doubtful whether people wash their hands properly, even for the prescribed period of 15 seconds, to achieve this. At present, there is a paucity of data on the efficacy of handwashing in relation to how people actually wash their hands on a day-to-day basis, both in the duration of handwashing and handwashing technique; in most of the intervention studies described earlier no attempt was made to time handwashes or to determine residual levels of contamination on the hands after handwashing. Microbiologic data suggest that, for some pathogens (eg, Salmonella), mechanical removal by handwashing alone is inefficient. These data, together with the results of in vivo panel testing of the effectiveness of handwashing and of ABHS, as described above, question the efficacy of handwashing in community-based groups and suggest that more work is needed to determine the efficacy of hand hygiene procedures under conditions normally encountered in the home and how hand hygiene procedures could be improved.

For ABHS, in vivo and in vitro testing suggest that these formulations are highly effective against bacterial pathogens and can produce a 3.5-log reduction on hands within 30 seconds and 4.0- to 5.0-log reduction after a 1-minute application against a wide range of species including Salmonella. It is possible, however, that the potential for increased benefits against bacterial infections compared with handwashing may be offset by reduced efficacy against important nonenveloped viruses such as rotavirus, some strains of rhinovirus, and possibly also norovirus. It has been argued that the higher impact of ABHS interventions against GI compared with RT infections is due to the fact that RT infections are predominantly viral. However, because the intervention data indicate that handwashing also

supports a stronger reduction in GI diseases compared with RT diseases, this seems unlikely. Some studies suggest that, to achieve satisfactory activity that includes all types of viruses, higher concentrations up to 80% ethanol should be advised. Other studies suggest that the efficacy of ABHS may be increased by increasing the volume of agent applied to the hands.²¹⁵

In formulating policies for hand hygiene, it would be convenient to be able to define what represents a "safe" residual level of contamination on the hands after hand hygiene, ie, sufficient to prevent infection transmission, but, because the infectious dose varies from one species to another and is dependant on the immune status of the recipient, this approach is untenable. The QMRA approach, as outlined earlier in this review, however, demonstrates that strategies that produce an increase in the log reduction on hands from 2 to 3 to 4 are accompanied by a significant incremental reduction in the risk of infection in a given population and could thus be worthwhile. This suggests that the health impact from promoting hand hygiene could be increased by developing and promoting procedures for use in the home and community that increase the log reduction of contamination on the hands. This involves identifying products and procedures (both soap-based and waterless products or wipes) that achieve high levels of removal and/or "kill" (alone or in combination) of the full range of gram-negative and gram-positive bacteria and enveloped and nonenveloped viruses and that deliver hand hygiene under conditions that people are prepared to employ in their busy and mobile daily lives. It also suggests that, particularly for "high-risk" situations as outlined below, there is advantage to be gained by promoting handwashing followed by use of ABHS to increase the log reduction.

Applying hand hygiene at the correct time: the need for hygiene education

The data presented in this review suggest that the favorable health impact from promoting hand hygiene could be further increased by getting people to practice hand hygiene not just more frequently but also at the right time. A number of studies show the relatively poor understanding of the principles of hygiene that is present in the community. This may be one of the factors responsible for the higher risk reductions observed in intervention studies of GI compared with RT infections. For example, knowledge regarding the need for handwashing after coughing or sneezing may not be as pervasive as knowledge about handwashing after defecation, and it may be that people understand better when to wash their hands during food-associated activities but not, for example, while handling contaminated tissues. Although some intervention studies described in

this review involved a component of education, it was not possible to determine the extent to which hygiene education that enhanced people's understanding of infection transmission also enhanced health outcome.

Because visible soiling is an unreliable indicator of the presence of pathogens on the hands, people are unlikely to wash their hands at the correct time unless they have been taught to do so or have some awareness of the chain of infection transmission in the home, ie, they are aware of when their hands may be contaminated. Whereas risks associated with food handling are largely confined to defined periods of time, for RT and skin infections (and person-to-person transmission of GI infection), the risk is ongoing and involves a large proportion of our ongoing daily activities. Thus, whereas it is possible for hand hygiene advice associated with food hygiene to be rule based, this is not the case for other types of infections. In the event of a flu pandemic, the advice issued by the UK Health Protection Agency²¹⁶ to "wash hands frequently" is unlikely to be effective unless people have some idea of the times when their hands are likely to be contaminated with flu virus.

Although current thinking about hygiene promotion tends toward a view that the most effective way to change behavior is by mass social marketing of single rule-based hygiene messages,⁴ the data presented in this review suggest that the complexity and shifting nature of the ID threat is such that a rule-based approach to hygiene is inadequate to meet current public health needs. The need is for an approach founded on awareness of the chain of infection transmission and how it differs for different groups of infections. Hygiene education needs to be consistently incorporated as part of hand hygiene promotion programs if people are to properly understand the risks and adapt their behavior accordingly.

DEVELOPING A FRAMEWORK FOR HAND HYGIENE PROMOTION IN THE HOME

Based on the data presented in this review, we propose that, in promoting hand hygiene, significant improvements in health impact could be achieved by giving better guidance to people, first, on how to choose the best methods for hand hygiene (handwashing and/or use of ABHS) based on the situation and showing them how to apply it properly and why this is important. Secondly, it means stressing when it is important to apply hand hygiene, ie, what are the risk situations or critical control points at which hand hygiene needs to be applied.

Although the level of risk varies according to the occupants of the home (eg, presence of children, pets, ill people) and their immune status, based on the risk assessment approach as outlined earlier in this review,

the critical control points or situations in which hand hygiene is indicated are as follows:

- after using the toilet (or disposing of human or animal feces);
 - after changing a baby's diaper and disposing of the feces;
 - immediately after handling raw food (eg, chicken, raw meat);
 - before preparing and handling cooked/ready-to-eat food;
 - before eating food or feeding children;
- but also
- after contact with contaminated surfaces (eg, rubbish bins, cleaning cloths, food contaminated surfaces);
 - after handling pets and domestic animals;
 - after wiping or blowing the nose or sneezing into the hands;
 - after handling soiled tissues (self or others', eg, children);
 - after contact with blood or body fluids (eg, vomit and others);
 - before and after dressing wounds;
 - before giving care to an "at-risk" person; and
 - after giving care to an infected person.

In choosing the appropriate option for hand hygiene, there are 3 possibilities: either handwashing with soap, use of ABHS (or other effective waterless-based sanitizers), or handwashing followed by use of ABHS. A possible framework for informing appropriate choice according to the particular situation is outlined in Fig 4. This suggests that, in situations in the home and community that are "standard risk" (perhaps better described as situations not specifically regarded as "high risk"), either handwashing or use of ABHS may be chosen. Within this, however, there are factors that advise, or in some cases dictate, choice, for example, handwashing is only an option when there is access to soap and water, whereas use of ABHS is not an option when hands are heavily soiled (although people are likely to choose handwashing in this situation, prompted by the need to "clean" their hands). As discussed previously, there will always be situations in the home in which there is increased risk, either because there is a known source of infection or someone who is at increased risk of becoming infected. These situations are summarized in Table 20. These situations may relate to activities that are carried out routinely in the home, such as handling of raw meat and poultry, or involve household members such as pregnant women or young babies who are otherwise healthy but at increased risk of (or from) infection. They also relate to "nonroutine" situations such as a person in the home who is infected with a cold, or norovirus or other GI infections, or to situations in which there is someone

who is at increased risk of infection as a result of underlying illness, immunosuppressive drug treatment, or needing catheter or wound care. Although much of the "health care" carried out at home is done by trained caregivers, increasingly, there are situations in the home in which simple but risky actions are carried out by household members. In all of these "increased risk" situations, as outlined in Table 20, it is suggested that handwashing followed by use of an ABHS should be encouraged.

In persuading people to change behavior, one of the key factors is "removing barriers to action."²¹⁷ Lack of convenient access to a sink is a significant barrier to compliance, and time pressure is a barrier to getting people to wash their hands thoroughly. A key benefit of ABHS is that they offer the means to apply hand hygiene in situations in which there is limited or no access to a soap and water. In home care situations, ABHS offer an alternative to handwashing in situations in which other pressures mitigate against finding the time to visit the bathroom for handwashing, for example, when caring for a baby in the nursery or a sick person. They also offer a substitute for handwashing in "out of home" settings such as offices and public places, such as public transport or animal exhibits, at which access to soap and water is a particular problem and all of which offer frequent opportunities for hand transmission of infection. Promoting use of ABHS has the potential to get people to undertake hand hygiene more frequently and at critical times. In response to concerns about the possibility of a flu pandemic, The Centers for Disease Control and Prevention recommend the use of ABHS for use as an alternative to handwashing.²¹⁸ In the event of a flu pandemic, it seems particularly important to encourage people to adopt good hand hygiene in public places. In health care settings, links between use of ABHS and increased hand hygiene compliance and reduced infection rates has been observed.²¹⁹ In applying the framework outlined in Fig 4, our intention is that this should not be regarded as an "either handwashing or ABHS" situation; the fundamental aim should be to encourage more people to undertake hand hygiene procedures wherever possible at critical times.

In view of the fact that hands are part of a complex system of infection transmission pathways, it must also be considered whether hand hygiene can, or should, be promoted in isolation. Because people are reluctant to comply with handwashing, together with the microbiologic data showing the potential for transfer via hand and food contact surfaces and cloths to hands, which increase as the frequency occurrence of contamination of these surfaces increases, it would seem that, to maximize the health impact from hand hygiene promotion, it should be

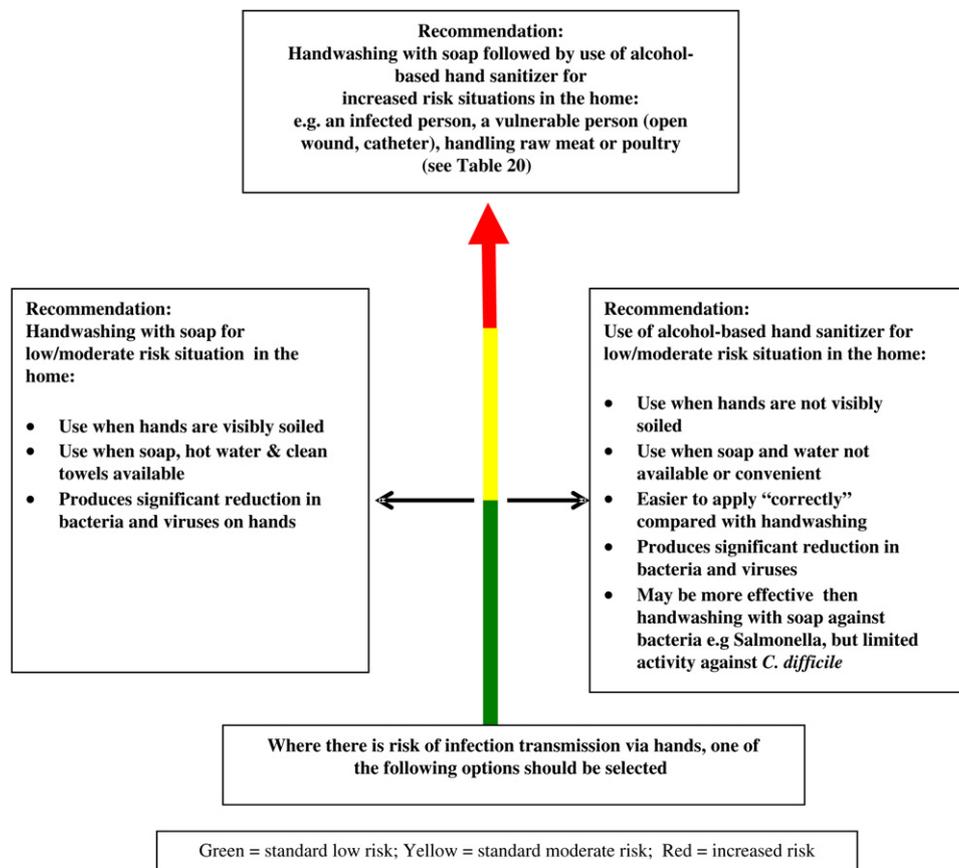


Fig 4. Choosing the most appropriate hand hygiene procedure.

combined with promotion of hygiene in general, including hygienic cleaning of critical surfaces. If nothing else, this could raise awareness that hand contamination can arise from touching apparently clean surfaces. We are concerned that emphasis on handwashing alone without putting it within the context of other aspects of hygiene is encouraging the perception that handwashing is all that is required, ie, “if you wash your hands you won’t get sick.”

The aim of this report has been to review the evidence base for hand hygiene and develop a practical framework from it for promoting an effective approach to hand hygiene in home and community settings. Provision of detailed guidelines for hand hygiene is outside the scope of this review. For such guidelines the reader is referred to the IFH guidelines and training resource on home hygiene. As part of its work in promoting home hygiene, the IFH has produced “Guidelines for Prevention of Infection and Cross Infection in the Domestic Environment” and “Recommendations for Selection of Suitable Hygiene Procedures for Use in the Domestic Environment.”^{220,221} These documents are based on the concept of a risk-based approach and give detailed guidance on hand hygiene

in the context of all aspects of home hygiene including food hygiene, general hygiene, personal hygiene, care of pets, and others. Most recently, the IFH has also produced a teaching/self-learning resource on home hygiene.²²² This is based on the IFH Guidelines and Recommendations but is designed to present home hygiene theory and practice in simple practical language that can be understood by those with relative little infection control training or background.

CONCLUSIONS

Infectious diseases circulating in the community remain a significant concern, both in developed and developing countries. The global burden of ID accounts for over 13 million deaths annually but, whereas the majority of deaths occurs in the developing world, infection also causes approximately 4% of deaths in developed countries.²²³ Although mortality from ID has declined in the developed world, trends in morbidity suggest a change in the pattern of ID rather than declining rates. Several demographic, environmental, and health care trends, as reviewed in this report, are combining to make it likely that the threat of ID will increase

Table 20. Increased risk situations in the home

Routine day-to-day situations		Nonroutine situations	
Increased risk from source of infection in the home	People who are otherwise healthy but at increased risk of infection	Increased risk from infected family members	People at increased risk of infection
Handling of raw meat, poultry, fish, fruit, and vegetables	Young babies, elderly adults, pregnant women	Family members infected with colds, flu, norovirus, Salmonella, Shigella, and others	Patients home from hospital or outpatients including people with catheters, wounds, or others
Family members or pets that are colonized or infected with, for example, Salmonella, <i>C difficile</i> , MRSA	People in poor living conditions		People undergoing drug treatment; people with underlying illness, eg, diabetes, HIV

in coming years, rather than decline. One such factor is the rising proportion of the population in the community who are more vulnerable to infection. An important part of current European and US health policy is commitment to shorter hospital stays. A key requirement is to ensure that the increased health provision at home is not accompanied by an increase in ID risks; otherwise, the cost savings gained by care in the community are likely to be overridden by costs of rehospitalization. Even for the “healthy community,” ID represents a significant economic burden because of absence from work and school and added health care costs. Secondary infections can produce complications, and some infections may be associated with the development of diseases such as cancer or other chronic conditions, which can manifest at a later date. Those responsible for ensuring that the public are protected from infection in health care facilities are now realizing that their ability to manage the problem is hampered by spread of pathogens such as MRSA, *C difficile*, and norovirus in the community and the home, and the number of infected people or carriers who come into their facilities, and are looking for ways to address this by engaging the public to adopt more rigorous standards of hygiene.

One of the things that is apparent from newly emerging data, and that is reflected in this review, is the extent to which common infections circulating in the community are hygiene related. This suggests, in turn, that hygiene promotion could have a significant benefit in terms of improved public health and well-being; in particular, the data highlight the extent to which viruses (norovirus, rotavirus, rhinovirus, influenza, and other viruses) are responsible for hygiene-related diseases now circulating in the community.

The main conclusions from this review are as follows:

- ID circulating in the home and community is a serious public health problem in the developed as well as the developing world.

- Good hygiene practice is key to reducing the burden of ID in the home and community.
- Hand hygiene is a key component of good hygiene practice in the home and community and can produce significant benefits in terms of reducing the incidence of infection, most particularly for gastrointestinal infections but also for respiratory tract and skin infections.
- Decontamination of hands can be carried out either by handwashing with soap or by the use of waterless hand sanitizers, which achieve a log reduction in bacterial and viral contamination on hands by the removal of contamination or by killing the organisms in situ. The health impact of hand hygiene within a given community can be increased by using products and procedures, either alone or in sequence, that maximize the log reduction of both bacteria and viruses on hands.
- The impact of hand hygiene in reducing ID risks could be increased by convincing people to apply hand hygiene procedures correctly (eg, wash their hands correctly) and at the correct time.
- To optimize health benefits, promotion of hand hygiene must be accompanied by hygiene education and should also involve promotion of other aspects of hygiene, for example, surface and cloth hygiene.

FURTHER RESEARCH

This report highlights a number of areas in which additional data are needed:

- Further studies are needed to characterize the frequency of, and factors associated with, ID transmission in noninstitutional settings such as the home.
- Further studies are needed to assess the relative efficacy of hand hygiene procedures in reducing hand contamination (handwashing with soap and use of

ABHS, involving different “contact/application/rinsing” times, and others). This includes the following: (1) in vivo panel tests to determine the reduction in bacteria and viruses on hands under controlled conditions. Committee European Normalisation or ASTM tests now provide standard test models for comparing the efficacy of handwashing with the use of waterless hand sanitizer products, under defined conditions. They provide an economic approach (relative to intervention studies) that can be used, alone or in combination with QMRA, to inform hygiene policy and/or the design of intervention studies. (2) Field studies to determine log reduction in counts on hands in relation to how people actually wash their hands or apply ABHS in their homes.

- Additional data are needed to understand how, when, and why people practice hand hygiene at home and how this relates to their understanding of ID transmission and risks.
- Intervention studies are needed to determine the health impact of hand hygiene promotion with hygiene education, compared with hygiene promotion without education. This should also include understanding how hand hygiene combines with surface hygiene to influence health outcome.
- Intervention studies are needed to determine the potential for an increase in health impact from promoting use of ABHS in conjunction with handwashing (ie, handwashing followed by use of ABHS) or as a supplement to handwashing (in situations in which access to water is limited), compared with the promotion of handwashing alone.

The authors thank Dr. Michele Pearson, Centers for Disease Control and Prevention, Atlanta, GA, for her very valuable and extensive contributions to the preparation of this review.

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