The effects of test variables on the efficacy of hand hygiene agents

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Background: Hand hygiene is essential to interrupting disease transmission in health care facilities. Multiple hand hygiene agents are currently available for use in the health care setting. To evaluate the utility of these agents, both the user acceptability and the efficacy need to be evaluated. Different hand hygiene test methodologies have been used to measure the efficacy of these agents, but efficacy results vary depending on variations to key parameters in these methodologies. The purpose of this study was to evaluate the effect of test variables on the efficacy of hand hygiene agents.

Methods: Both a comprehensive literature review and original hand hygiene efficacy studies were undertaken. The literature review was conducted using a Medline search, and hand hygiene efficacy studies were conducted under the American Society for Testing and Materials (ASTM). E 1174 Standard Test Method for Evaluation of the Effectiveness of Health Care Personnel Handwash Formulation.

Results: The literature review and our original data showed that the following variables affected the hand hygiene efficacy measurements: hand jewelry, experimental contamination versus normal flora, method of application of test organism, hand hygiene agent, concentration of active ingredient, volume of hand hygiene agent, duration of application of hand hygiene agent, method of application of hand hygiene agent, and study method (human challenge trial versus in vitro suspension test).

Conclusions: Although many methodological variables affect efficacy results, infection control professionals in their analysis of product information should always assess the results in light of the following key variables: concentration and type of active ingredient, duration of exposure to hand hygiene agent, volume of hand hygiene agent applied, test organism, and study method (ie, human challenge vs. in vitro suspension test). (Am J Infect Control 2004;32:69-83.)

Health care-associated infections most commonly result from person-to-person transmission via the hands of health care personnel. Therefore, effective hand hygiene is essential to the prevention and control of these infections.[1] With the proper use of hand hygiene agents, lower rates of infectious disease have been documented in health care facilities,[2-4] child care centers,[5-6] and households.[7-8]

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Currently many different hygiene agents are available for use in the hospital. These agents differ principally in their active ingredient(s) and method of application (eg, wash with water, waterless or alcohol-based handrub, or waterless wipes). The 2 key issues in assessing the clinical utility of different hand hygiene agents are compliance and efficacy. Factors demonstrated to be associated with compliance have included accessibility, potential for skin irritation, texture, ease of use, and education on proper hand hygiene.[1] Human challenge trials and in vitro suspension tests have been used to assess the efficacy of various hand hygiene agents.[9-47] Such studies have served to provide recommendations on the proper use of hand hygiene agents (eg, contact time) and to compare the efficacy of different agents.

Hand hygiene agent efficacy has been measured using various methodologies. Although these methodologies, in general, follow a schedule of contamination, hand hygiene, and recovery, many other variables may affect the measurement of hand hygiene efficacy. Since these test variables may affect the reported efficacy, results of published studies must be evaluated independently, and the reported efficacy of each hand

hygiene agent must be considered relative to other agents studied using the same test methodology. To better understand and interpret the results of published hand hygiene studies, the effects of test variables need to be assessed.

This paper will describe current methods of assessing the efficacy of hand hygiene agents and the impact of test variables that can affect the study results. Specifically, we review all studies published in English, from 1964 to 2002, that assessed the efficacy of hand hygiene agents. In addition, we use our data to evaluate the impact of a number of test variables.

METHODS

Literature review

The literature was obtained via a Medline search from 1966 through January 2003, of all articles with the following keywords: hand hygiene, hand antisepsis, hand disinfection, and glove juice. We also reviewed all articles listed under handwashing and the subheading "Methods" and all articles cross-listed under handwashing and efficacy. References listed in articles were also reviewed.

General test methodology

Our hand hygiene study data were obtained using the framework of the American Society for Testing and Materials (ASTM) E 1174 Standard Test Method for Evaluation of the Effectiveness of Health Care Personnel Handwash Formulations.[48] Briefly, this method involves contaminating a volunteer's hands with a liquid suspension of *Serratia marcescens* and washing with a test hand hygiene agent. We also used MS2, a bacteriophage, as an additional test organism to assess the efficacy of hand hygiene agents against a nonenveloped virus. The level of reduction of microorganisms from the hands was measured by the amount of organisms recovered from the hands using the glove juice method before and after hand hygiene. In the glove juice method, the volunteer's hands were placed in oversized gloves filled with a sampling solution and were massaged for 60 seconds. Neutralizing ingredients, tween-80, lecithin, sodium thiosulfate, proteose peptone, and tryptone were added to the sampling solution to quench the antimicrobial action of the hand hygiene agent applied to the hands; this neutralizing solution was validated using ASTM E 1054-91. After the hand massage, 5 mL of glove juice was retrieved aseptically from the gloves, serially diluted, and assayed in duplicate by the spread plate technique (*S marcescens*) and double agar layer technique (MS2) with tryptic soy agar plates. Remaining organisms were enumerated at 24 hours (MS2) and 48 hours (*S marcescens*) and were used to estimate, for MS2, the number of plaque-forming units per (PFU/mL) and, for *S marcescens*, the number of colony-forming units per milliliter (CFU/mL).

All subjects were healthy volunteers. These studies were approved by the University of North Carolina's School of Medicine Institutional Review Board, and written informed consent was obtained from all volunteers prior to study participation. Volunteers were screened for skin disorders and allergies and excluded if they had any of the following conditions: eczema, psoriasis, any other chronic skin condition, nonintact skin, or allergies to any test agent.

Statistical analysis

All statistical analyses were conducted using Microsoft Excel (Microsoft, Bellevue, Wash). For all efficacy results determined using ASTM E 1174, the log reductions of *S marcescens* and MS2 were calculated by subtracting the average $\log_{10}$-transformed remaining microorganisms (CFU/mL or PFU/mL) from the average $\log_{10}$-transformed baseline level of microorganisms recovered from the contaminated hands (CFU/mL or PFU/mL). These efficacy results and other single-variable comparisons were analyzed using 95% confidence intervals and 2 sample, equal variance, 2-tailed student *t* tests. The N used for these calculations was determined by analyzing each hand as a separate entity, and the number of microorganisms remaining on each hand was calculated as an average of duplicate plate counts.

Volunteer variables

Hand volume measurements were made in cubic centimeters on each volunteer's hands using a hand volumeter (Smith & Nephew Roylan, Germantown, Wis). Regression analysis was conducted to examine a correlation between hand volumes and measures of efficacy. In addition, the volunteer's dominant hand was self-reported and recorded as right, left, or equal. After hand hygiene with 61% ethyl alcohol handrub (Avagard, 3M Healthcare, St Paul, Minn), 70% ethyl alcohol and 0.005% silver iodide handrub (Surfacine, Intelligent Biocides, Tyngsborough, Mass), 0.2% benzethonium chloride handwash (Pure Cleanse, Puresoft Solutions, Newfields, NH), 2% chlorhexidine gluconate hand wash (Bactoshield, Steris, St Louis, Mo), and a nonantimicrobial handwash (Soft Soap Hand Soap, Colgate-Palmolive Company, New York, NY), the effect of hand dominance on the level of reduction of microorganisms from the hands was assessed by comparing the efficacy measurements for the dominant and nondominant hand using paired *t* tests. Finally, after their participation, all volunteers were evaluated by a physician for the presence of skin

irritation. Volunteers with skin irritation were followed until resolution. The relationship of the hand hygiene agent tested and the presence of skin irritation after the study was examined by stratification of active ingredient and method of use.

Contamination

To test the effect of moisture on the hands on the reduction of microorganisms with alcohol-based handrubs, the volunteers' contaminated hands were either air-dried for 60 seconds or were completely dried, in the opinion of the volunteer, using a hair dryer set to a cool setting. The compatibility of the test organisms, *S marcescens* and MS2, was also assessed by assaying both the organisms separately (control) and the organisms combined (experimental). The organisms were aliquoted into sterile microfuge tubes, vortexed, 10-fold serially diluted, and assayed using the spread plate technique (*S marcescens*) and the double agar layer technique (MS2).

Hand hygiene

To test the effects of the quantity of hand hygiene agent on efficacy, 2 different volumes of a 62% ethyl alcohol handrub (Alcare, Steris, St Louis, Mo) were tested: 3 g, as recommended by the manufacturer,[49] and 7 g, in accordance with the manufacturer's efficacy study protocol (Laboratory Report Methods #310-306-6395 for Alcare, Steris, Mentor, Ohio, July 1997). In addition, the variable of application time was tested with a 62% ethyl alcohol handrub using both a 10-second hand hygiene episode and a hand hygiene episode that lasted until the volunteers felt their hands were dry, ranging from 3 to 12 minutes. Finally, the effect of the method of use was examined by conducting hand hygiene efficacy studies with plain tap water as a control for the physical removal of *S marcescens* with water-based handwashes (0.75% chlorhexidine gluconate [Primakare, Steris, St Louis, Mo], 2% chlorhexidine gluconate, 4% chlorhexidine gluconate [Bactoshield, Steris, St Louis, Mo], 1% triclosan [Prevacare, Johnson & Johnson, Arlington, Tex], and 0.2% benzethonium chloride). The percentage of log reduction attributed to physical removal and chemical inactivation was estimated using the log reduction of tap water achieved.

Recovery

The comparative efficiency of recovery for both the glove juice recovery method and in vitro suspension test method was assessed by inoculating both a latex glove and a sterile flask each containing 75 mL of sampling and neutralizing solution with *S marcescens* and MS2. After 5 minutes of stirring and massaging, respectively, samples were aseptically retrieved and assayed. In addition, the effect of proteinaceous materials on hands was tested by conducting hand hygiene efficacy studies using a 61% ethyl alcohol handrub and nonantimicrobial control handwash with standard solutions and with solutions that did not contain any proteins. These nonproteinaceous solutions included a phosphate buffer solution for the test organism suspension rather than a tryptic soy broth, and the sampling solution was used without the neutralizing ingredients. Instead, the neutralizing ingredients were added to the diluent solution rather than to the glove juice sampling solution.

RESULTS

Literature review

Tables 1 and 2 summarize the results of multiple published studies that assessed the efficacy of hand hygiene agents.[9-47] They also display selected important variables associated with these test methodologies such as hand hygiene agent concentration, quantity of agent used, application time, test microorganism, and test method. In addition, the efficacy of different hand hygiene agents reported in the literature as well as the size of the study are displayed. A large number of potential factors that could affect the efficacy of hand hygiene agents have been described in the literature (Table 3).

Test methodology

We have experimentally evaluated several of the most important variables described in the literature for their effect on the outcome of hand hygiene efficacy studies (Table 4).

Volunteer variables. The volume of the volunteers' hands varied 2.3-fold, from 275 to 640 cm^3, with the average right-hand volume being 430 cm^3 and the average left-hand volume being 421 cm^3. Regression analysis showed no correlation between hand size and the log reduction of microorganisms (data not shown). In addition, the level of reduction of microorganisms from the hands did not differ significantly between the dominant and nondominant hand (data not shown), disproving the theory that the dominant hand would wash the nondominant hand more vigorously, thus resulting in a higher log reduction of microorganisms.

An analysis of skin irritation stratified by test hand hygiene agent did not reveal a consistent association between any specific agent or method of application and frequency of skin irritation (Table 5). However, overall 28% of volunteers developed skin irritation. Skin irritation consisted of 3 to 25 discrete papules spread diffusely on the hands but without vesicle

Table 1. Comparative efficacy (bacterial reduction) of test agents using various methodologies

Antiseptic	Concentration %	Volume	Contact time	Test organism
Ethanol (wipe)	30	N/A	15 s	normal flora
Ethanol	54	1 handful	until dry	normal aerobic flora
Ethanol	54	1 handful	until dry	normal anaerobic flora
Ethanol	61	2-3 mL	avg. 12.7	normal flora
Ethanol (foam)	62	2.5 g	30 s	*E coli*
Ethanol	62	3 mL	360 s	*S marcescens*
Ethanol	70	5 mL	60 s	*A baumannnii*
Ethanol	70	5 mL	30 s	*S aureus*
Ethanol	70	5 mL	30 s	*E coli*
Ethanol	70	5 mL	60 s	MRSA
Ethanol	70	5 mL	until dry	normal aerobic flora
Ethanol	70	5 mL	until dry	normal anaerobic flora
Ethanol	80	0.5 mL	20 s	MRSA
Ethanol	85	9 mL	30 s	*S aureus*
Ethanol	85	9 mL	30 s	*P aeruginosa*
Ethanol	85	9 mL	30 s	*E coli*
Isopropanol	49	5 mL	30 s	*E coli*
Isopropanol	60	5 mL	15 s	normal aerobic flora
Isopropanol	60	5 mL	15 s	normal anaerobic flora
Isopropanol	60	5 mL	until dry	normal aerobic flora
Isopropanol	60	5 mL	until dry	normal anaerobic flora
Isopropanol	70	5 mL	until dry	normal flora
Isopropanol	70	2 mL	15 s	normal aerobic flora
Isopropanol	70	2 mL	15 s	normal anaerobic flora
Parachlorometaxylenol	1	3 mL	20 s	*S marcescens*
Benzalkonium and ethanol	0.2 / 76.9-81.4	3 mL	180 s	normal flora
Povidone iodine and ethanol	0.5 / 83	3 mL	45 s	normal flora
Povidone iodine and ethanol	0.5 / 83	3 mL	45 s	normal flora
Povidone iodine and ethanol	0.5 / 83	3 mL	180 s	normal flora
Povidone iodine and ethanol	0.5 / 83	3 mL	180 s	normal flora
CHG and ethanol	0.05 / 60	5 mL	until dry	normal aerobic flora
CHG and ethanol	0.05 / 60	5 mL	until dry	normal anaerobic flora
CHG and ethanol	0.05 / 95	10 mL	until dry	normal flora
CHG and ethanol	1 / 60	5 mL	30 s	*E coli*
CHG and alcohol	4 / 4	1 mL	10 s	*C difficile*
CHG and isopropanol	0.5 / 70	10 mL	180 s	*M roseus*
CHG and isopropanol	0.3 / 70	5 mL	15 s	normal aerobic flora
CHG and isopropanol	0.3 / 70	5 mL	15 s	normal anaerobic flora
CHG and isopropanol	0.5 / 60	5 mL	until dry	normal aerobic flora
CHG and isopropanol	0.5 / 60	5 mL	until dry	normal anaerobic flora
CHG and isopropanol	0.5 / 70	5 mL	~15 s	*M roseus*
CHG and isopropanol	0.5 / 70	5 mL	30 s	*E coli*
CHG and isopropanol	0.5 / 70	N/A	30 s	MRSA
CHG and isopropanol	0.5 / 70	N/A	30 s	MSSA
CHG and isopropanol	4 / 4	4 mL	30 s	normal aerobic flora
CHG and isopropanol	4 / 4	4 mL	30 s	normal anaerobic flora
CHG and isopropanol	4 / 4	4 mL	180 s	normal aerobic flora
CHG and isopropanol	4 / 4	4 mL	180 s	normal anaerobic flora
CHG and isopropanol	4 / 4	5 mL	15 s	normal aerobic flora
CHG and isopropanol	4 / 4	5 mL	15 s	normal anaerobic flora
CHG and isopropanol	4 / 4	5 mL	30 s	MRSA
Triclosan and isopropanol	0.5 / 70	5 mL	30 s	*E coli*
Triclosan and isopropanol	0.5 / 70	10 mL	180 s	*M roseus*
2-propanol, 1-propanol, mecetronium etilsulfphate	45 / 30 / 0.2	ND	30 s	VRE
2-propanol, chlorhexidine digluconate, hydrogen peroxide	0 / 0.5 / 0.45	ND	30 s	VRE
2-propanol, 1-chlorhexidine gluconate	70 / 0.5	ND	30 s	VRE
Povidone-iodine	7.5	5 mL	15 s	*M roseus*

Study type	Log reduction	N	Reference
Glove juice	0.008	12	Butz et al (1990)
Fingertip stamp	0.315	18	Myklebust (1985)
Fingertip stamp	0.421	18	Myklebust (1985)
Glove juice	0.39	26	Larson et al (2001)
Glove juice	2.5	12	Ayliffe et al (1988)
Glove juice	3.79	5	Paulson et al (1999)
Glass bead immersion	1.97	5	Cardoso et al (1999)
Glass bead immersion	3.67	10	Ayliffe et al (1978)
Glass bead immersion	3.4	10	Ayliffe et al (1978)
Glass bead immersion	3.51	5	Guilhermetti et al (2001)
Fingertip stamp	−0.344	18	Myklebust (1985)
Fingertip stamp	−0.413	18	Myklebust (1985)
Fingertip immersion	2.1	5	Huang et al (1994)
In vitro	5.27	ND	Kampf et al (2002)
In vitro	5.11	ND	Kampf et al (2002)
In vitro	5.31	ND	Kampf et al (2002)
Glass bead immersion	3.4	10	Ayliffe et al (1988)
Glove juice	0.1	10	Larson et al (1986)
Glove juice	0.09	10	Larson et al (1986)
Fingertip stamp	−0.140	18	Myklebust (1985)
Fingertip stamp	−0.164	18	Myklebust (1985)
Glove juice	0.799	40	Aly and Maibach (1979)
Glove juice	0.08	10	Larson et al (1986)
Glove juice	0.068	10	Larson et al (1986)
Glove juice	2.5	5	Paulson et al (1999)
Palm stamp method	0.0123	38	Minakuchi et al (1993)
Glove juice	0.61	29	Kawana et al (1993)
Glove juice	0.64	40	Nagai et al (1993)
Palm stamp method	1.21	37	Minakuchi et al (1993)
Palm stamp method	0.89	30	Kirita et al (1993)
Fingertip stamp	1.80	18	Myklebust (1985)
Fingertip stamp	1.68	18	Myklebust (1985)
Ringer's solution bowl	1.624	6	Lilly et al (1979)
Glass bead immersion	2.6	10	Ayliffe et al (1988)
Fingertip stamp	3.1	10	Bettin et al (1994)
Kneading fluid	2.96	30	Bartzokas et al (1987)
Glove juice	0.054	10	Larson et al (1986)
Glove juice	0.008	10	Larson et al (1986)
Fingertip stamp	3.00	18	Myklebust (1985)
Fingertip stamp	3.00	18	Myklebust (1985)
Glove juice	5.5999	25	Ulrich (1982)
Glass bead immersion	3.1	12	Ayliffe et al (1988)
In vitro	8.63	18	Kampf et al (1998)
In vitro	8.47	18	Kampf et al (1998)
Finger stamp	1.00	18	Myklebust (1985)
Finger stamp	0.71	18	Myklebust (1985)
Finger stamp	1.18	18	Myklebust (1985)
Finger stamp	0.19	18	Myklebust (1985)
Glove juice	0.073	10	Larson et al (1986)
Glove juice	0.072	10	Larson et al (1986)
Glass bead immersion	1.91	5	Guiihermetti et al (2001)
Glass bead immersion	3.1	24	Ayliffe et al (1988)
Kneading fluid	2.79	30	Bartzokas et al (1987)
In vitro	≥7.66	16	Kampf et al (1999)
In vitro	≥7.66	16	Kampf et al (1999)
In vitro	≥7.66	16	Kampf et al (1999)
Glove juice	4.9204	25	Ulrich (1982)

Table 1. Continued

Antiseptic	Concentration %	Volume	Contact time	Test organism
Povidone-iodine	7.5	5 mL	30 s	*S aureus*
Povidone-iodine	7.5	5 mL	30 s	*E coli*
Povidone-iodine	8	0.5 mL	20 s	MRSA
Povidone-iodine	10	0.25 mL	30 s	MRSA
Povidone-iodine	10	5 mL	30 s	MRSA
Povidone-iodine	10	5 mL	30 s	*A baumannnii*
CHG	0.5	5 mL	until dry	normal flora
CHG	2	4 mL	15 s	normal flora
CHG	2	N/A	avg. 21.1 s	normal flora
CHG (foam)	2.5	2.5 mL	15 s	*S aureus*
CHG	4	N/A	30 s	MRSA
CHG	4	N/A	30 s	MSSA
CHG	4	N/A	15 s	*S marcescens*
CHG	4	0.5 mL	20 s	MRSA
CHG (foam)	4	"golf ball sized"	15 s	normal flora
CHG (foam)	4	2.5 mL	15 s	*S aureus*
CHG	4	3 mL	15 s	normal flora
CHG	4	4 mL	15 s	normal flora
CHG	4	5 mL	30 s	*S aureus*
CHG	4	5 mL	30 s	*E coli*
CHG	4	5 mL	30 s	*A baumannnii*
CHG	4	5 mL	30 s	*E coli*
CHG	4	5 mL	30 s	*E coli*
CHG	4	5 mL	30 s	*P aeruginosa*
CHG	4	5 mL	30 s	*P aeruginosa*
CHG	4	5 mL	60 s	*S aureus*
CHG	4	5 mL	140 s	normal flora
CHG	4	10 mL	180 s	*M roseus*
Chlorhexidine digluconate	0.5	N/A	30 s	MRSA
Chlorhexidine digluconate	0.5	N/A	30 s	MSSA
Chlorhexidine digluconate	2	N/A	30 s	MRSA
Chlorhexidine digluconate	2	N/A	30 s	MSSA
Chlorhexidine digluconate	4	N/A	30 s	MRSA
Chlorhexidine digluconate	4	N/A	30 s	MSSA
Chlorhexidine digluconate	4	2 mL	30 s	*S marcescens*
Chlorhexidine digluconate	4	2 mL	30 s	*Micrococcus*
Chlorhexidine digluconate	4	5 mL	30 s	*S marcescens*
Chlorhexidine digluconate	4	5 mL	30 s	*Micrococcus*
Triclosan	1	3 mL	15 s	normal flora
Triclosan	2	5 mL	30 s	*E coli*
Triclosan	2	10 mL	180 s	*M roseus*
Plain soap	N/A	ND	30 s	*S aureus/P pyocyanea*
Plain soap	N/A	0.5 mL	20 s	MRSA
Plain soap	N/A	1 mL	10 s	*C difficile*
Plain soap	N/A	2 mL	30 s	*S marcescens*
Plain soap	N/A	2 mL	30 s	*Micrococcus*
Plain soap	N/A	2.5 mL	15 s	*S aureus*
Plain soap	N/A	3 mL	15 s	normal flora
Plain soap	N/A	3 mL	20 s	*S marcescens*
Plain soap	N/A	4 mL	15 s	normal flora
Plain soap	N/A	5 mL	15 s	normal aerobic flora
Plain soap	N/A	5 mL	15 s	normal anaerobic flora
Plain soap	N/A	5 mL	30 s	*S aureus*
Plain soap	N/A	5 mL	30 s	*E coli*
Plain soap	N/A	5 mL	30 s	MRSA
Plain soap	N/A	5 mL	30 s	*A baumannnii*
Plain soap	N/A	5 mL	140 s	normal flora

Study type	Log reduction	N	Reference
Glass bead immersion	3.02	10	Ayliffe et al (1978)
Glass bead immersion	3.76	10	Ayliffe et al (1978)
Fingertip immersion	2.1	5	Huang et al (1994)
In vitro	4.819	?	McLure and Gordon (1992)
Glass bead immersion	3.76	5	Guilhermetti et al (2001)
Glass bead immersion	1.82	5	Cardoso et al (1999)
Glove juice	0.83	41	Aly and Maibach (1979)
Glove juice	0.0054	10	Larson and Laughon (1987)
Glove juice	−0.07	24	Larson et al (2001)
Glass bead immersion	2.09	74	Ayliffe et al (1990)
In vitro	5.92	18	Kampf et al (1998)
In vitro	8.52	18	Kampf et al (1998)
Glove juice	3.85	36	Rosenberg et al (1976)
Fingertip immersion	1.55	5	Huang et al (1994)
Glove juice	0.015	10	Larson and Laughon (1987)
Glass bead immersion	2.24	74	Ayliffe et al (1990)
Glove juice	0.127	12	Butz et al (1990)
Glove juice	0.0256	10	Larson and Laughon (1987)
Glass bead immersion	2.4	11	Ayliffe et al (1978)
Glass bead immersion	2.78	8	Ayliffe et al (1978)
Glass bead immersion	1.07	5	Cardoso et al (1999)
Glass bead immersion	1.806	15	Lee et al (1988)
Glass bead immersion	1.653	15	Lee et al (1988)
Glass bead immersion	1.693	15	Lee et al (1988)
Glass bead immersion	1.72	15	Lee et al (1988)
Glass bead immersion	2.66	74	Ayliffe et al (1990)
Ringer's solution bowl	0.867	6	Lilly et al (1979)
Kneading fluid	1.03	30	Bartzokas et al (1987)
In vitro	0.38	18	Kampf et al (1998)
In vitro	1.46	18	Kampf et al (1998)
In vitro	4.49	18	Kampf et al (1998)
In vitro	6.92	18	Kampf et al (1998)
In vitro	7.12	18	Kampf et al (1998)
In vitro	6.92	18	Kampf et al (1998)
Glass bead immersion	2.33	12	Nicoletti et al (1990)
Glass bead immersion	1.92	12	Nicoletti et al (1990)
Glass bead immersion	2.81	12	Nicoletti et al (1990)
Glass bead immersion	2.31	12	Nicoletti et al (1990)
Glove juice	0.151	12	Butz et al (1990)
Glass bead immersion	2.3	7	Ayliffe et al (1988)
Kneading fluids	1.03	30	Bartzokas et al (1987)
Ringer's solution bowl	2.54	8	Lowbury et al (1964)
Fingertip immersion	1.41	5	Huang et al (1994)
Fingertip stamp	3.2	10	Bettin et al (1994)
Glass bead immersion	2.27	12	Nicoletti et al (1990)
Glass bead immersion	1.50	12	Nicoletti et al (1990)
Glass bead immersion	2.05	74	Ayliffe et al (1990)
Glove juice	0.289	12	Butz et al (1990)
Glove juice	2.29	5	Paulson et al (1999)
Glove juice	0.00893	10	Larson and Laughon (1987)
Glove juice	0.038	10	Larson et al (1986)
Glove juice	0.033	10	Larson et al (1986)
Glass bead immersion	2.31	10	Ayliffe et al (1978)
Glass bead immersion	2.41	10	Ayliffe et al (1978)
Glass bead immersion	1.96	5	Guilhermetti et al (2001)
Glass bead immersion	1.12	5	Cardoso et al (1999)
Ringer's solution bowl	−0.008	6	Lilly et al (1979)

CHG, Chlorhexidine gluconate; *MRSA*, methicillin resistant *S aureus*; *MSSA*, methicillin sensitive *S aureus*; *VRE*, vancomycin resistant enterococci; *NA*, not applicable; *ND*, not decipherable.

Table 2. Comparative efficacy (viral reduction) of test agents using various methodologies

Antiseptic	Concentration %	Volume	Contact time	Test organism
Ethanol	7	0.1 mL	360 s	RSV
Ethanol	50	8 mL	120 s	MS2
Ethanol	50	8 mL	120 s	Poliovirus
Ethanol (pH = 11.5)	50	3 mL	110 s	MS2
Ethanol	60	1 mL	20 s	Adenovirus
Ethanol	60	1 mL	20 s	Rhinovirus
Ethanol	60	1 mL	20 s	Rotavirus
Ethanol	70	20 uL	60 s	MS2
Ethanol	70	5 mL	30 s	MS2
Ethanol	70	5 mL	60 s	Rotavirus
Ethanol	70	8 mL	120 s	MS2
Ethanol	70	8 mL	120 s	Poliovirus
Ethanol	80	ND	60 s	Poliovirus
Ethanol	80	5 mL	30 s	Poliovirus Sabin 1 an
Ethanol	80	5 mL	180 s	Poliovirus
Ethanol	85	9 mL	30 s	Rotavirus
Ethanol	85	9 mL	120 s	Adenovirus
Ethanol	85	9 mL	180 s	Poliovirus
Ethanol	90	ND	60 s	Poliovirus
Ethanol	90	5 mL	30 s	K1-K5
isopropanol	70	20 uL	60 s	MS2
isopropanol	70	8 mL	120 s	MS2
N-propanol	70	8 mL	120 s	MS2
Propan 2-ol	70	5 mL	60 s	Rotavirus
CHG and isopropanol	0.004/0.004	0.1 mL	360 s	RSV
CHG and isopropanol	0.5/70	20 uL	60 s	MS2
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Adenovirus 5
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Poliovirus 1
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Poliovirus 2
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Coxsackie B3
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Coxsackie B4
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Echovirus 9 Hill
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Echovirus 9 Barty
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Simian Virus 40
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Vaccinia MVA
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Influenza A/WSN
Ethanol and isopropanol and methylphenol	93.3/10/0.1	2.8 mL	600 s	Fowl plague virus
Povidone iodine	7.5	0.1 mL	360 s	RSV
Povidone iodine	7.5	5 mL	30 s	MS2
Povidone iodine	7.5	5 mL	30 s	K1-K5
Povidone iodine	7.5	5 mL	30 s	Rotavirus
Povidone iodine	10	20 uL	60 s	MS2
CHG	0.08	0.9 mL	7200 s	Coxsackie virus
CHG	0.08	0.9 mL	7200 s	Echovirus
CHG	0.08	0.9 mL	7200 s	Poliovirus
CHG	4	20 uL	60 s	MS2
Chlorhexidine digluconate	4	5 mL	30 s	Rotavirus
Triclosan	2	5 mL	30 s	Rotavirus
Plain soap	N/A	3 mL	30 s	Rotavirus
Plain soap	N/A	3 mL	30 s	Poliovirus 1
Plain soap	N/A	5 mL	30 s	MS2
Plain soap	N/A	5 mL	30 s	K1-K5
Plain soap	N/A	5 mL	30 s	Poliovirus Sabin 1an

CHG, Chlorhexidine gluconate; *MRSA*, methicillin resistant *S aureus*; *MSSA*, methicillin sensitive *S aureus*; *VRE*, vancomycin resistant enterococci; *NA*, not applicable; *ND*, not decipherable.

*Graphical extrapolation.

Study type	Log reduction	N	Reference
in vitro	1	2	Krilov and Harkness (1993)
in vitro	0.13	4	Jones et al (1991)
in vitro	0.10	4	Jones et al (1991)
Glass bead immersion	2.1	10	Jones et al (1991)
Figerpad method	4.6	12	Sattar et al (2000)
Fingerpad method	2.4	12	Sattar et al (2000)
Fingerpad method	4.5	12	Sattar et al (2000)
Fingerpad method	~0.5*	4	Woolwine and Geberding (1995)
Glass bead immersion	1.09	7	Davies et al (1993)
Glass bead immersion	2.853	9	Bellamy et al (1993)
In vitro	0.70	4	Jones et al (1991)
In vitro	0.60	4	Jones et al (1991)
In vitro	1.21	3	Eggers (1989)
Glass bead immersion	0.42	4	Davies et al (1993)
PBS immersion	0.56	3	Eggers (1989)
In vitro	5.25	ND	Kampf et al (2002)
In vitro	6.62	ND	Kampf et al (2002)
In vitro	4.37	ND	Kampf et al (2002)
In vitro	5.12	3	Eggers (1989)
Glass bead immersion	2.33	4	Davies et al (1993)
Fingerpad method	~0.2*	4	Woolwine and Geberding (1995)
In vitro	0.41	4	Jones et al (1991)
In vitro	0.00	4	Jones et al (1991)
Glass bead immersion	3.145	9	Bellamy et al (1993)
In vitro	1	2	Krilov and Harkness (1993)
Fingerpad method	~0.3*	4	Woolwine and Geberding (1995)
PBS immersion	2.1*	1	Schurmann and Eggers (1983)
PBS immersion	1.0*	1	Schurmann and Eggers (1983)
PBS immersion	0.2*	1	Schurmann and Eggers (1983)
PBS immersion	1.1*	1	Schurmann and Eggers (1983)
PBS immersion	1.8*	1	Schurmann and Eggers (1983)
PBS immersion	0.7*	1	Schurmann and Eggers (1983)
PBS immersion	1.3*	1	Schurmann and Eggers (1983)
PBS immersion	0.9*	1	Schurmann and Eggers (1983)
PBS immersion	>1.4*	1	Schurmann and Eggers (1983)
PBS immersion	>2.5*	1	Schurmann and Eggers (1983)
PBS immersion	>2.5*	1	Schurmann and Eggers (1983)
In vitro	1	2	Krilov and Harkness (1993)
Glass bead immersion	2.8	7	Davies et al. (1993)
Glass bead immersion	2.06	2	Davies et al (1993)
Glass bead immersion	1.284	9	Bellamy et al (1993)
Fingerpad method	0.6*	4	Woolwine and Geberding (1995)
In vitro	0.001	1	Narang and Codd (1983)
In vitro	0.02	1	Narang and Codd (1983)
In vitro	0.001	1	Narang and Codd (1983)
Fingerpad method	0*	4	Woolwine and Geberding (1995)
Glass bead immersion	0.459	18	Bellamy et al (1993)
Glass bead immersion	2.125	9	Bellamy et al (1993)
Glass bead immersion	1.172	18	Bellamy et al (1993)
PBS immersion	1.9	3	Schurmann and Eggers (1985)
Glass bead immersion	2.29	6	Davies et al (1993)
Glass bead immersion	1.26	6	Davies et al (1993)
Glass bead immersion	2.1	4	Davies et al (1993)

Table 3. Potential factors that could alter the efficacy of hand hygiene agents measured experimentally

Test methodology: volunteer variables
Skin condition of test volunteer
Hand size
Hand dominance
Fingernail length
Presence of fingernail polish
Presence of artificial fingernails
Hand jewelry (eg, rings)
Test methodology: contamination
Experimental contamination versus normal flora
Experimentally inoculated test microorganism
Level of contamination
Method of contamination (dry versus rub)
Duration of contamination (drying or rubbing)
Extent of application of test microorganism (ie, whole hand versus fingertips)
Test methodology: hand hygiene
Concentration of active ingredient
Method of application
Volume of hand hygiene agent used
Hand hygiene application time
Extent of application of hand hygiene agent (ie, whole hand versus fingertips)
Washing schedule
Test methodology: recovery
Method of test organism recovery
Determination of efficacy using an in vitro method versus an in vivo method (ie, human challenge)
Method of drying after hand hygiene (ie, use of paper towels versus air dry)
Calculation of log reduction (ie, comparison to baseline versus comparison to reference agent)

Table 4. Test variables examined for effect on efficacy results

Test methodology: volunteer variables
Hand volume
Hand dominance
Frequency and severity of skin irritation following study participation
Test methodology: contamination
Length of drying time for test organisms on hands
Inclusion of multiple test organisms
Test methodology: hand hygiene
Test agent volume
Duration of hand hygiene application
Method of use (ie, handwash, handrub, hand wipe)
Test methodology: recovery
Method of recovering organisms from hands
Sampling solution composition
Protein content of solutions applied to the hands

formation. In some cases, diffuse erythema was observed. In all cases the skin irritation was mild, did not require specific therapy, and was transient. Volunteers who developed skin irritation had a higher frequency of developing irritation on further challenges, and subsequent irritation tended to develop more papules and with an earlier time course.

Contamination. Although alcohol-based handrub agents are considered to be more effective for use on dry hands, increasing the drying time of the contaminating organisms on the hands was found to have no significant ($P > .05$) impact on the efficacy of the 62% ethyl alcohol handrub (Fig 1). In addition, the inclusion of 2 microorganisms in the same inoculum appeared to have little, if any, effect on the titers of the organisms (*S marcescens*, control titer 9.40×10^8 CFU/mL, experimental titer 1.10×10^9 CFU/mL; MS2 bacteriophage, control titer 2.18×10^8 PFU/mL, experimental titer 3.43×10^8 PFU/mL).

Hand hygiene. The experiments with the variation of exposure time and volume of the 62% ethyl alcohol handrub demonstrated that the volume of agent used clearly affected the efficacy of hand hygiene with 7 grams statistically superior at all washes except wash 10 (Fig 2). Second, the effect of exposure time on efficacy was somewhat variable, but rubbing until dry was more effective at 4 of the 5 washes (Fig 3). Third, combining 3 grams of agent with a 10-second application time was significantly less effective ($P < .001$) than using 7 grams of the agent and rubbing until dry (Fig 4). Finally, Table 6 shows the percentage of log reduction of *S marcescens* because of physical removal and because of chemical inactivation with the antimicrobial handwash agents. The chemical inactivation achieved by the active ingredients was variable (0%-45% total $\log_{10}$ reduction), and physical removal contributed greatly to the efficacy measurement achieved with each handwash agent.

Recovery. The glove juice recovery method was efficient at recovery of *S marcescens* (88%) and MS2 (86%). The level of recovery was similar for the glove juice method and sterile glass flasks for both *S marcescens* (~0.1 - $\log_{10}$ difference) and MS2 (~0.02 - $\log_{10}$ difference). Also, the presence of protein on the hands did not interfere with inactivation or removal of microbes by the tested hand hygiene agents (Table 7).

DISCUSSION

Hand hygiene is considered a key ingredient in the prevention and control of health care-associated infections.[1] In recent years, there has been renewed emphasis on methods of improving compliance such as use of more accessible alcohol-based handrubs and hand wipes. In addition, in the hospital there has been an increasing use of antiseptic agents as compared with soap and water. Determining the efficacy of various hand hygiene agents is critical for developing public health policy and for providing guidance to individual institutions as they choose among the available hand hygiene agents. Unfortunately, the use

Table 5. Relationship between test agent and skin irrigation

Active ingredient (N = 10)	Wash type	% Irritation
60% EtOH	Handrub	40
61% EtOH	Handrub	40
62% EtOH	Handrub	44
61% EtOH/1% CHG	Handrub	0
70% EtOH/0.5% silver	Handrub	20
0.5% PCMX/40% SD alcohol	Wipe	20
0.4% benzalkonium chloride	Wipe	60
0.75% CHG	Handwash	60
2% CHG	Handwash	0
4% CHG	Handwash	0
1% triclosan	Handwash	0
0.2% benzethonium chloride	Handwash	33
Nonantimicrobial control	Handwash	40
	Overall handrub (N = 50)	31
	Overall Wipe (N = 20)	40
	Overall Handwash (N = 60)	23

CHG, Chlorhexidine gluconate; *EtOH*, ethyl alcohol; *PCMX*, para-chloro-meta-xylenol; *SD*, standard denatured.

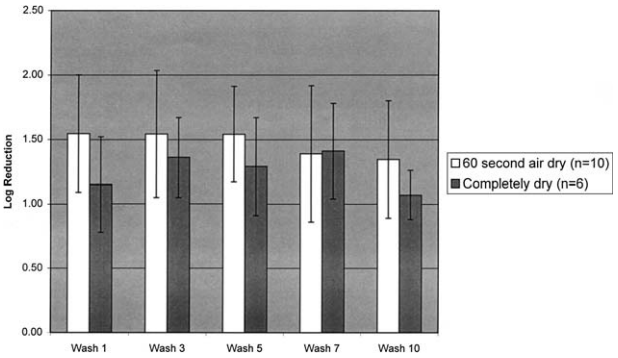

Fig 1. The effect of drying time after contamination on log reductions of *S marcescens* with the use of 61% ethyl alcohol (bars represent 95% confidence intervals).

of differing methodologies and the failure to test multiple agents in the same study makes comparisons of different agents difficult, if not impossible. We have reviewed the literature of human challenge trials and in vitro suspension tests, and we have experimentally evaluated several parameters within a standard hand hygiene methodology in order to assess what variables may affect the efficacy measurements of hand hygiene agents.

Our review of the literature (Tables 1-2) suggests that the experimental contamination versus normal flora, concentration of active ingredient, volume of agent, application time, and human challenge versus in vitro study type are important variables that affect the reported efficacy of hand hygiene agents (Table 8). In general, increased concentrations of the active ingredient, increased volumes of the agent used, and increased application time of hand hygiene agent tend to show improved efficacy. Hand hygiene efficacy studies that measure the reductions of transient microorganisms applied to the hands, rather than of normal hand microflora, also appear to be associated with increased efficacy measurements. In vitro suspension tests tend to produce higher log reduction measurements than any of the test methods used in the human challenge trials (ie, glove juice, glass bead immersion, Ringer's solution bowl, palm stamp, fingerpad method). In this brief review, it is impossible to fully discuss and compare individual studies and each variable demonstrated to affect hand hygiene efficacy.

In addition to examining differences among comparative studies, several other studies in the published literature have examined directly the effects of other variables in the test methodology on the reported efficacy measurements. Based on these published studies, the following variables have been identified to significantly affect hand hygiene efficacy measurements: hand jewelry, technique for application of test organisms, and test agent volume (Table 8). Test subjects who wore rings on hands have been demonstrated to have increased levels of microorganisms on the hands.[50,51] In experimental contamination of the hands, the test organism was applied by either an immersion or rubbing technique; the removal of microorganisms has been reported to be significantly greater with the immersion technique rather than the rubbing technique.[52,53] An experimental study that tested the effects of varying volumes of agents (1 mL and 3 mL) after multiple washes verified that the quantity of soap is another important variable in hand hygiene methodologies.[54]

These published experiments also identified the following variables as having no significant effect on the efficacy measurements of hand hygiene agents: soap pH, method of drying after hand hygiene, use of neutralizing ingredients, temperature of the sampling solution, and fingertip recovery techniques (Table 8). Soap pH was not found to have a significant effect on the efficacy measurements over short periods of time (ie, <3 hours).[55] After hand hygiene, various drying procedures including use of a cloth towel, paper towel, warm air dryer, and air evaporation were evaluated in their ability to affect the efficacy results; no significant differences among any of the groups were found.[56] The necessity of incorporating neutralizing ingredients in the sampling solution has been demonstrated, and the inclusion of these ingredients did not appear to have any adverse effect on the activity of the hand hygiene agent because of neutralization residue on the hands.[57,58] Temperature differences (6 ^{o}C or 23 ^{o}C)

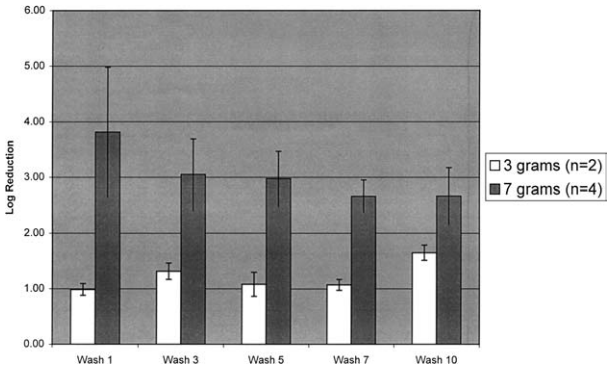

Fig 2. The effect of volume of 62% ethyl alcohol on log reduction of *S marcescens* (bars represent 95% confidence intervals).

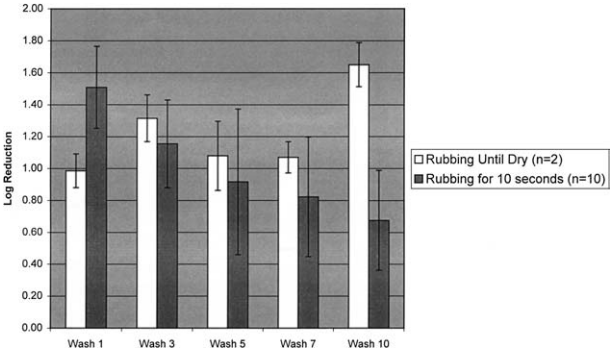

Fig 3. The effect of duration of handrubbing with 62% ethyl alcohol on the log reduction of *S marcescens* (bars represent 95% confidence intervals).

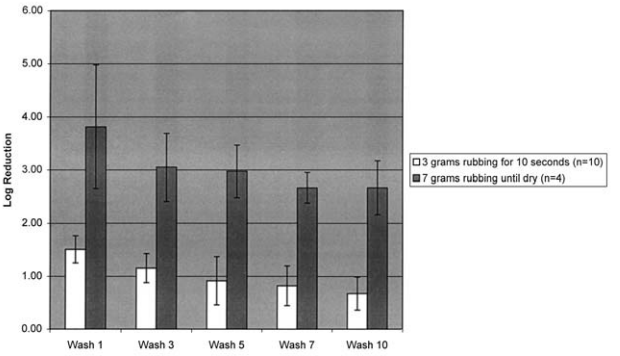

Fig 4. The effect of volume of 62% ethyl alcohol and duration of hand rubbing on log reduction of *S marcescens* (bars represent 95% confidence intervals).

Table 6. Percentage of log reductions of *S marcescens* attributable to physical removal and chemical inactivation

Active Ingredient(s) (N = 10)	% log reduction because of physical removal	% log reduction because of chemical inactivation
0.75% CHG	66	34
2% CHG	55	45
4% CHG	64	36
1% triclosan	80	20
0.2% benzethonium chloride	100	0

CHG, Chlorhexidine gluconate; *EtOH*, ethyl alcohol; *PCMX*, para-chloro-meta-xylenol; *SD*, standard denatured.

of the sampling solution did not show any consistent effect on efficacy results.[58] Two different recovery techniques, fingertip immersion in petri dish fluid and fingertip glass bead technique, were examined in their effect on the measured efficacy of selected agents; these recovery methods alone showed no effect on the measurement of efficacy.[53]

Our data demonstrated that the following variables had a significant effect on efficacy: method of use of hand hygiene agent, duration of hand hygiene application, and test agent volume (Table 8). The efficacy measurements for hand hygiene wash agents showed that bacterial reduction was attributed to both physical removal and chemical inactivation; for hand hygiene alcohol-based handrub agents, efficacy measurements are attributed solely to chemical inactivation. Although both the application time and volume of test agent affected the efficacy results, the combination of these 2 variables (ie, 3 g of agent used for 10 s versus 7 g of agent used until dry) produced a more drastic effect ($P < .001$). These 2 variables are so often modified in hand hygiene efficacy studies that it is crucial to examine them both, in addition to any reported efficacy measurement. Ideally, these parameters should be set to mimic realistic conditions; in this case, 7 g of test agent could not be rubbed into the hand in a reasonable amount of time (up to 12 min) available between patient care events.

Our data demonstrated that the following variables did not have a significant effect: hand volume, hand dominance, inclusion of multiple test microorganisms, length of drying time for test microorganisms on hands, and method of recovering organisms from hands (Table 8). Because no effects were observed, hand volume does not need to be considered in performing efficacy studies of hand hygiene agents. In addition, hand hygiene studies can be conducted more efficiently by making reduction measurements on both hands and including multiple test microorganisms. When including more than 1 test microorganism, a simple compatibility experiment such as that described earlier could be used to validate the use of

Table 7. Log reduction (95% confidence interval) of *S marcescens* with and without proteinaceous material applied to the hands using 2 hand hygiene agents

	With proteinaceous material (N = 10)	Without proteinaceous material (N = 6)	*P* value
Nonantimicrobial soap			
Wash 1	1.87 (1.64-2.10)	1.39 (1.18-1.61)	.01
Wash 3	1.73 (1.50-1.96)	1.28 (1.15-1.43)	.02
Wash 5	1.66 (1.40-1.91)	1.25 (1.00-1.49)	.05
Wash 7	1.56 (1.30-1.83)	1.25 (1.04-1.46)	.13
Wash 10	1.60 (1.37-1.84)	1.18 (0.99-1.37)	.02
61% Ethyl alcohol			
Wash 1	1.55 (1.09-2.00)	1.07 (0.53-1.61)	.22
Wash 3	1.55 (1.05-2.03)	0.91 (0.56-1.26)	.09
Wash 5	1.54 (1.17-1.92)	0.54 (0.35-0.73)	.002
Wash 7	1.39 (0.86-1.91)	0.52 (0.32-0.72)	.03
Wash 10	1.35 (0.89-1.80)	0.18 (−0.06-0.43)	.003

these multiple microorganisms in the same inoculum. Including multiple organisms allows one to efficiently test efficacy on surrogates of different types of pathogens; it also enhances comparisons among multiple hand hygiene agents. Although the length of air-drying time after microbial contamination in the ASTM E 1174 methodology had been specified as 60 seconds, the volunteers' hands were not completely dry after this time. Because the efficacy of alcohol-based handrubs can be affected when used on wet hands, we modified the standard 60-second air dry to drying with a cool hair dryer until the volunteers felt their hands were dry. Our data did not demonstrate that wet hands adversely affected the efficacy results; therefore, the ASTM E 1174 method suggested drying time is likely appropriate even for testing the efficacy of waterless handrub agents. When holding all other variables constant, the method of recovery either by glove juice or in vitro suspension did not produce any significant differences. However, other differences inherent to the study methodology can lead to significant differences in measurement of efficacy using the human challenge and in vitro study methodologies.

Future studies on additional variables should lead to improved understanding of efficacy results. Volunteer hand properties and effects that have not been well described include fingernail length, presence of fingernail polish, and presence of artificial fingernails. Variations in the extent of contamination and extent of hand hygiene on the hands (ie, fingertips or entire hand) have not been previously studied. In addition, hand hygiene episodes vary from instructing volunteers to follow a structured method to encouraging volunteers to affect their usual manner. Differences in efficacy measurements made with various human challenge recovery techniques (ie, glove juice, glass bead immersion, Ringer's solution bowl, palm stamp, fingerpad method) are also undefined. Currently, no standard method of reporting efficacy results exists. Investigators have reported test agent efficacy measurements as a reduction from a baseline level of organisms recovered from the hand, a reduction from the quantitative amount of organisms applied to the hand, or the level of microorganisms remaining on the hands as compared with level of microorganisms remaining on the hands after use of a reference product. We support the method used in ASTM E 1174, which is reporting reduction of microorganisms from the hand compared with a baseline level of microorganisms from the hand.

From our own experiments, additional research is warranted to fully understand the effect of a variable on efficacy measurements (Table 8). For example, although the presence of protein on the hands was not shown to adversely affect the efficacy measurements of an alcohol-based handrub, results showed significantly increased efficacy when proteinaceous solutions were

Table 8. Effects of test variables on measured efficacy of hand hygiene agents based on review of the literature and current experiments

Alters efficacy
Hand jewelry
Experimental contamination versus normal flora
Method of application of test organism
Hand hygiene agent
Concentration of active ingredient
Volume of hand hygiene agent*
Duration of application of hand hygiene agent*
Method of application of hand hygiene agent*
Study method (human challenge trial versus in vitro suspension test)
No effect on efficacy
Hand dominance*
Hand volume*
Use of multiple microorganism*
Duration of contamination drying time*
Soap pH
Recovery method*
Temperature of sampling solution
Use of neutralizing ingredients
Method of drying after hand hygiene
Effect on efficacy unknown/unclear
Fingernail length
Presence of fingernail polish
Presence of artificial fingernails
Extent of application of test microorganism (ie, whole hand versus fingertips)
Extent of application of hand hygiene agent (ie, whole hand versus fingertips)
Presence of protein on hands*
Study method of human challenge trials (ie, glove juice, glass bead immersion, Ringer's solution bowl, palm stamp, fingerpad method)

*Our experiments.

applied to the hands. These results are somewhat surprising because protein is well-known to impair the efficacy of germicides. These results warrant further investigation and explanation before concluding that proteinaceous material has a positive effect on efficacy measurements. In addition, the presence of skin irritation after study participation has never been reported, and further studies are required to determine the cause of this reaction. We agree with the ASTM recommendation that volunteers should be prescreened and excluded if they have a prior skin condition and would add the requirement that a physician evaluate volunteers after participation in the study to assess frequency and severity of skin irritation.

Medical science needs a standardized hand hygiene efficacy methodology with regard to variables known to affect results. Although the ASTM E 1174 standard methodology is currently available, many variations of it are used. For example, the Food and Drug Administration based its tentative final monograph for over-the-counter health care antiseptic drug products on the ASTM E 1174 method with some modifications that have been shown experimentally to affect efficacy measurements.[59] Parameters requiring standardization include properties of the test volunteers' hands (ie, hand jewelry, fingernail polish, fingernail length, artificial fingernails), method and extent of application of test microorganisms, volume of hand hygiene agent used, and duration of application of hand hygiene agent. Furthermore, these parameters should be standardized to mimic realistic conditions to produce the most meaningful efficacy measurements for setting public health policies and choosing appropriate hand hygiene agents for use in health care institutions.

CONCLUSION

Although many methodological variables affect efficacy results, infection control professionals in their analyses of product information should always assess the results in light of the following key variables: concentration and type of active ingredient, duration of exposure to hand hygiene agent, volume of hand hygiene agent applied, test organism, and study method (ie, human challenge vs in vitro suspension test).

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