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Appendix

ORIGINAL ARTICLE

Hand Hygiene Noncompliance and the Cost of Hospital-Acquired Methicillin-Resistant *Staphylococcus aureus* Infection

Keith L. Cummings, MD, MBA; Deverick J. Anderson, MD, MPH; Keith S. Kaye, MD, MPH

BACKGROUND. Hand hygiene noncompliance is a major cause of nosocomial infection. Nosocomial infection cost data exist, but the effect of hand hygiene noncompliance is unknown.

OBJECTIVE. To estimate methicillin-resistant *Staphylococcus aureus* (MRSA)-related cost of an incident of hand hygiene noncompliance by a healthcare worker during patient care.

DESIGN. Two models were created to simulate sequential patient contacts by a hand hygiene–noncompliant healthcare worker. Model 1 involved encounters with patients of unknown MRSA status. Model 2 involved an encounter with an MRSA-colonized patient followed by an encounter with a patient of unknown MRSA status. The probability of new MRSA infection for the second patient was calculated using published data. A simulation of 1 million noncompliant events was performed. Total costs of resulting infections were aggregated and amortized over all events.

SETTING. Duke University Medical Center, a 750-bed tertiary medical center in Durham, North Carolina.

RESULTS. Model 1 was associated with 42 MRSA infections (infection rate, 0.0042%). Mean infection cost was $47,092 (95% confidence interval [CI], $26,040–$68,146); mean cost per noncompliant event was $1.98 (95% CI, $0.91–$3.04). Model 2 was associated with 980 MRSA infections (0.098%). Mean infection cost was $53,598 (95% CI, $50,098–$57,097); mean cost per noncompliant event was $52.53 (95% CI, $47.73–$57.32). A 200-bed hospital incurs $1,779,283 in annual MRSA infection–related expenses attributable to hand hygiene noncompliance. A 1.0% increase in hand hygiene compliance resulted in annual savings of $39,650 to a 200-bed hospital.

CONCLUSIONS. Hand hygiene noncompliance is associated with significant attributable hospital costs. Minimal improvements in compliance lead to substantial savings.

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Hospital-acquired infections cause more than 98,000 deaths annually in the United States[1] and are associated with increased cost and duration of hospitalization.[2] Each year, hospital-acquired infections occur in 7%–10% of hospitalized patients during their hospital stay.[3]

Compounding the issue of hospital-acquired infections is the increasing degree of resistance of pathogens to antimicrobial agents. The foremost such example is methicillin-resistant *Staphylococcus aureus* (MRSA). Among intensive care units that report to the Centers for Disease Control and Prevention, there has been a nearly 3-fold increase in the proportion of *S. aureus* infections caused by MRSA, from 22% in 1995 to 63% in 2004. This trend is worrisome, as MRSA infections result in greater morbidity and higher costs than do infections due to methicillin-susceptible *S. aureus*. For example, hospital-acquired bloodstream infections due to MRSA lead to a 3-fold increase in total direct costs compared with total direct costs associated with methicillin-susceptible *S. aureus* infections.[4] Thus, continuing increases in MRSA prevalence will cause aggregate costs related to hospital-acquired infection to increase greatly.

Noncompliance with hand hygiene recommendations is widely recognized as the most important modifiable cause of hospital-acquired infections.[5-8] Indeed, in their 2008 Patient Safety Goals[9] The Joint Commission requires that, as the primary means of preventing hospital-acquired infections, hospitals comply with World Health Organization and/or Centers for Disease Control and Prevention hand hygiene guidelines.[2,10-12] Unfortunately, rates of compliance with hand hygiene recommendations are unacceptably low in most hospitals.[9,12,13] Results from most studies suggest that overall hand hygiene compliance rates are below 50%.[3]

Costs associated with hospital-acquired infections and MRSA have been widely published.[4,14-16] Little is known, however, regarding the actual costs of individual behaviors that lead to these infections, such as noncompliance with hand

From the Department of Medicine, Duke University Medical Center, Durham, North Carolina (K.L.C., D.J.A.); and the Department of Medicine, Wayne State University, Detroit Medical Center, Detroit, Michigan (K.S.K.).

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hygiene during patient care. Quantifying the cost of hand hygiene noncompliance will provide clinicians, administrators, and patient advocacy groups with concrete data that can be used to improve the accountability of hand hygiene noncompliance among healthcare workers. The purpose of this study was to quantify the cost of a single episode of hand hygiene noncompliance by a healthcare worker in a hospital setting relative to risk for MRSA transmission.

METHODS

Model Design and Study Setting

A stochastic mathematical model was constructed to simulate the outcome of a single episode of hand hygiene noncompliance. Data regarding hospital admissions and episodes of contact between patients and healthcare workers were collected from Duke University Medical Center, a 750-bed tertiary care hospital in Durham, North Carolina. Other data, such as MRSA prevalence rates and rates of hand hygiene compliance, were extracted from previously published reports.[17,18]

The mathematical model was used to simulate a specific scenario in which a healthcare worker contacts 2 patients consecutively and fails to comply with hand hygiene guidelines after contact with the first patient (patient 1) and before contact with the second patient (patient 2). Using the model, we calculated the probability of MRSA transmission from patient 1 to the healthcare worker and then from the healthcare worker to patient 2. Embedded in this analysis is a calculation of transmission potential, which estimates the probability that patient 1 was MRSA-positive and the probability that patient 2 was MRSA-negative. In addition, the model was used to calculate the probability of patient 2 developing an infection due to MRSA after becoming colonized. These probabilities were then used in a simulation of 1 million episodes of hand hygiene noncompliance.

Published data regarding hospital prevalence of MRSA, rates of hospital-acquired transmission of MRSA, and rates of hand hygiene compliance served as inputs to the model (see Table 1). Data regarding daily contacts between patients and healthcare workers and data regarding average length of hospital stay were obtained from quality improvement studies previously conducted at Duke University Medical Center and were also included as inputs to the model.

Simulations were performed under 2 different scenarios. The first scenario (the normal risk scenario) simulated hand hygiene noncompliance by a healthcare worker between contacts with 2 patients of unknown MRSA status (ie, both patients 1 and 2 may or may not have been colonized with MRSA). The second scenario (the high-risk scenario) involved hand hygiene noncompliance between contacts with 2 patients by a healthcare worker in which patient 1 was colonized or infected with MRSA and the MRSA status of patient 2 was unknown.

Model Inputs, Calculations, and Simulations

Inputs. On the basis of published data, the prevalence of MRSA in inpatient settings was estimated to be 4.63% (95% confidence interval [CI], 4.53%–4.72%).[4] Therefore, the prob-

TABLE 1. Model Inputs and Calculated Values

Model input	Calculation method	Calculated value (95% CI)
MRSA total hospital prevalence, %	…	4.63 (4.53–4.72)
$P[\text{pt}(+)]$[a]	…	0.0463
$P[\text{pt}(-)]$[b]	…	0.9537
Incidence of hospital-acquired MRSA, %	…	1.43
Mean no. of daily room visits	…	56.38 (52.36–60.40)
Frequency of direct contact per room visit, %	…	57.24
Mean no. of days per hospitalization	…	6.26
Frequency of hand hygiene compliance, %	…	55.13
Rate of infection after colonization	…	0.29
Cost of MRSA HAI, lognormal distribution, $	…	7,228–164,392
Projected mean no. of direct contacts per patient-day	Daily room visits × (direct contacts per room visit)	32.27
Projected mean no. of NDCs per patient-day	Direct contacts per patient-day × (1 − compliance)	14.50 (13.26–15.77)
Projected mean no. of CEs per patient-day	NDCs per patient-day × $P[\text{pt1}(+) \cap \text{pt2}(-)]$	0.64 (0.57–0.71)
Projected mean no. of CEs per hospitalization	(CEs per day) × (days per hospitalization)	4.01
Projected mean no. of hospital-acquired MRSA colonizations per CE	Incidence of hospital-acquired MRSA colonization / CEs per hospitalization	0.0036
Projected mean no. of MRSA infections per CE	(MRSA colonizations per CE) × rate of infection after colonization	0.0010

NOTE. CE, contaminated encounter; CI, confidence interval; HAI, hospital-acquired infection; MRSA, methicillin-resistant *Staphylococcus aureus*; NDC, noncompliant direct contact.

[a] Probability that a randomly selected patient is MRSA-positive.

[b] Probability that a randomly selected patient is MRSA-negative.

ability of a random patient being MRSA-positive, $P[\mathrm{pt}(+)]$, was 0.0463. Conversely, the probability of a random patient being MRSA-negative, $P[\mathrm{pt}(-)]$, was 0.9537. In addition, it was estimated on the basis of published data that 31% (95% CI, 30%–32%) of MRSA cases would be detected more than 48 hours after admission and would thus be categorized as hospital-acquired.[4] The transmission of MRSA in the hospital to previously uncolonized inpatients was therefore calculated to occur in 1.43% of inpatients ($0.04626 \times 0.31 = 0.0143$).

Direct contact was defined as physical contact between a healthcare worker and a patient. The numbers of direct contacts per patient-day were estimated from Duke University Medical Center data and published data.[5] At Duke University Medical Center in February 2008, the mean number of times a patient room was visited by a healthcare worker was 56.38 (95% CI, 52.36–60.40) per patient-day. A recent study from another institution revealed that 57.24% of room visits involve direct patient contact.[5] From these estimates, we calculated a rate of 32.27 direct contacts per patient-day. The mean days per hospitalization were calculated from Duke University Hospital data as 6.26 days per hospitalization.

The aggregate rate of hand hygiene compliance after patient room visits was estimated to be 45.1%. The rate of compliance after room visits involving direct patient contact was estimated to be 55.13%.[5] The probability of infection among newly colonized patients was estimated at 29%.[6]

Published estimates of total hospital cost associated with hospital-acquired MRSA infection span a broad range: mean infection cost estimates are $9,275–$110,493, and median infection cost estimates are $5,885–$49,734.[2,4,14,19-22] Abramson and Sexton[4] reported a median cost of $27,083 (range, $7,228–$164,392). The cost distribution reported in their study represented the median distribution among published studies; therefore, it was chosen as the basis of this study. In our model, we assigned a lognormal distribution to the range reported by Abramson and Sexton. Using the lower and upper limits of the published range as our 5% and 95% CI values, we generated a theoretical cost distribution curve with mean and median MRSA infection costs of $54,153 and $34,494, respectively. See Table 1 for model inputs and calculations.

Model calculations. The daily noncompliant direct contact (NDC) rate was calculated by multiplying daily contacts by (1 − compliance rate). The mean NDC rate was calculated to be 14.50 (95% CI, 13.26–15.77) per patient-day.

A contaminated encounter (CE) was defined as an NDC in which transmission of MRSA might occur; that is, the first patient contacted by the healthcare worker in the scenario was MRSA-positive *and* the second patient contacted was MRSA-negative. For simplification, healthcare workers were assumed to be MRSA-negative before contact with the first patient. The expected number of CEs per hospital stay was calculated as the product of the daily NDC rate, the probability that the NDC was a CE, and the mean length of a hospital stay in days. On the basis of these calculations, we estimated that the expected number of CEs per patient-day was 0.64 (95% CI, 0.57–0.71) and that the expected number of CEs per hospital stay was equal to $0.64 \times 6.26 = 4.01$. The expected rate of MRSA colonization per CE (MRSA/CE) was calculated by dividing the prevalence of hospital-acquired MRSA by the number of CEs per hospital stay: $0.0143/4.01 = 0.0036$ (Table 1).

Simulation

Simulation design. One million NDCs were simulated. The simulation model determined (1) whether an MRSA infection occurred after an NDC and (2) the cost of the subsequent infection. Total infection costs were then compiled and amortized over all 1 million NDCs to calculate a mean cost per NDC. The simulation was executed for 2 scenarios, a normal risk scenario (the MRSA status of both patients is unknown) and a high-risk scenario (patient 1 has positive MRSA status).

The simulation model used a set of 4 Boolean variables to define a single path for hospital-acquired MRSA infection (see Figure 1, for a detailed simulation flow, and Table 2). Boolean variables included the probability that patient 1 is colonized with MRSA ($P = 0.0463$), the probability that patient 2 is not colonized with MRSA ($P = 0.9537$), the probability of MRSA transmission ($P = 0.0036$), and the probability of MRSA infection ($P = 0.29$). Variables are summarized in Table 3. In the event that a simulated infection occurred, a cost was assigned to the event on the basis of a lognormal distribution (mean, $54,064; median, $34,459; 95% CI, $7,228–$164,392).

Normal and high-risk scenarios. In the normal risk scenario, the MRSA status of patient 1 was unknown. Therefore, all 4 Boolean variables were used to determine whether an infection occurred. In contrast, in the high-risk scenario patient 1 was assumed to be colonized or infected with MRSA. In this case, only 3 Boolean variables were included in the simulation (ie, patient 1 MRSA status, $P = 1.0$) (Figure 1).

Alternative model. Transmission of hospital-acquired MRSA is not caused exclusively by direct patient contact. While the role of the environment in MRSA transmission is not completely understood, studies have successfully isolated MRSA from environmental surfaces in rooms occupied by patients who are colonized with MRSA.[23] One study demonstrated an increased incidence of MRSA acquisition by patients who stayed in rooms that had previously been occupied by patients who were colonized or infected with MRSA.[24] Thus, it is likely that some hospital-acquired MRSA infections are caused by contact with contaminated environmental surfaces rather than by direct contact with a healthcare worker. Environmental surfaces can also become contaminated with MRSA during a patient visit by a healthcare worker who is colonized with MRSA. As a result, contamination of the environment can occur during a patient visit that does not involve direct patient contact (ie, during a routine visit, not necessarily during a CE). To address this environmental contamination scenario, we included a simulation based on the total number of room visits instead of the number of direct patient contacts only. This model derivation assumed

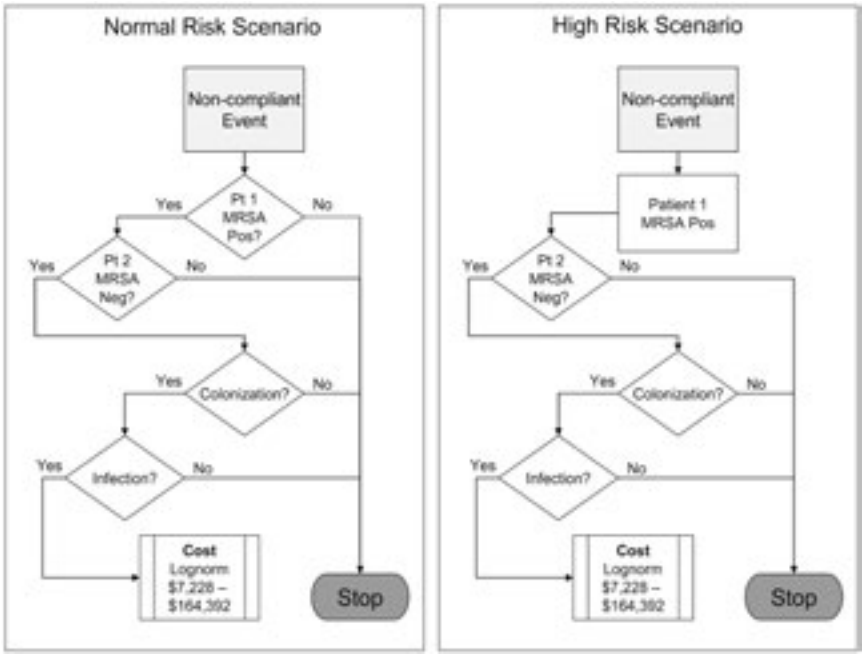

FIGURE 1. Simulation logic for likelihood of transmission of methicillin-resistant *Staphylococcus aureus* (MRSA) between 2 patients by the hands of healthcare workers. The normal risk scenario involves hand hygiene noncompliance by a healthcare worker between contact with 2 patients of unknown MRSA status. The high-risk scenario involves hand hygiene noncompliance between 2 patient contacts by a healthcare worker during which patient 1 was colonized or infected with MRSA and the MRSA status of patient 2 was unknown. Descriptions and probabilities for both scenarios are shown in Table 2. Pt, patient; Pos, positive; Neg, negative.

that each noncompliant event exhibited an equal probability of MRSA transmission regardless of whether direct patient contact occurred. In this model, we used the Dedrick[18] estimate for hand hygiene compliance of 45.1% after a patient room visit (not limited to direct patient contact). We used Duke data for mean daily room visits of 56.38 per patient-day (not limited to room visits with direct contact) as the basis for the number of room visits.

Secondary analysis. Simulation results were applied to a hypothetical 200-bed hospital operating at 85% occupancy with MRSA prevalence and hand hygiene compliance equal to national averages and patient contact rates equal to those of Duke University Medical Center estimates. In this secondary analysis, all patients in the hospital were assumed to have an unknown MRSA status. The expected annual hospital cost attributable to MRSA infection was calculated. Sensitivity analysis was performed on the hand hygiene compliance rate to determine the cost benefit of increasing hand hygiene compliance by 1%.

RESULTS

Normal Risk Scenario

The normal risk scenario is defined as hand hygiene noncompliance by a healthcare worker between contacts with 2 patients of unknown MRSA status. The normal risk simulation resulted in 44,284 CEs over the course of 1 million NDCs (Table 4). Subsequently, 143 episodes of hospital-acquired MRSA colonization occurred, resulting in 42 hospital-acquired MRSA infections. The mean cost per MRSA infection was $47,092 (95% CI, $26,040–$68,146). The median cost per infection was $22,353 (interquartile range [IQR],

TABLE 2. Simulation Logic for Likelihood of Transmission of Methicillin-Resistant *Staphylococcus aureus* (MRSA) between 2 Patients by the Hands of a Healthcare Worker (HCW)

Step	Event	Description	Probability
1	Noncompliant event	HCW is noncompliant with hand hygiene between 2 consecutive patient encounters	1.0
2	Patient 1 MRSA-positive?	First patient encountered is MRSA-positive	0.0463 or 1.0[a]
3	Patient 2 MRSA-negative?	Second patient encountered is MRSA-negative	0.9537
4	Colonization?	Patient 2 colonized by MRSA as a result of HCW encounter	0.0036
5	Infection?	Colonized patient 2 develops infection	0.29

[a] The normal risk scenario involved patients of unknown MRSA status; community prevalence is 4.63%. The high-risk scenario involved initial patients who were known to be positive for MRSA.

TABLE 3. Boolean and Lognormal Variables for Simulation Model

Value	Variable type	Normal scenario	High-risk scenario
Patient 1 colonized[a]	Boolean	0.0463	1.0
Patient 2 uncolonized[b]	Boolean	0.9537	0.9537
Colonizations per contaminated encounter[c]	Boolean	0.0036	0.0036
Infections per colonization[d]	Boolean	0.29	0.29
Cost per infection,[e] 95% CI, $	Lognormal	7,228–164,392	7,228–164,392

NOTE. CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus.*
[a] Probability that patient 1 is colonized with MRSA.
[b] Probability that patient 2 is not colonized with MRSA (1 − [patient 1 colonized]).
[c] Probability of patient 2 colonization given a contaminated encounter.
[d] Probability of patient 2 infection given patient 2 colonization.
[e] Cost given patient 2 infection.

$17,006–$42,996). The mean cost per NDC was thus $1.98 (95% CI, $0.91–$3.04).

High-Risk Scenario

The high-risk scenario is defined as hand hygiene noncompliance between 2 patient contacts by a healthcare worker during which patient 1 was colonized or infected with MRSA and the MRSA status of patient 2 was unknown. The high-risk simulation resulted in 953,912 CEs over the course of 1 million NDCs, resulting in 3,340 episodes of hospital-acquired MRSA colonization and 980 episodes of hospital-acquired MRSA infection (Table 4). These infections resulted in a mean cost of $53,598 (95% CI, $50,098–$57,097) and a median cost of $35,045 (IQR, $18,106–$72,022). The mean cost per NDC was thus $52.53 (95% CI, $47.73–$57.32).

Alternative Model

The alternative model is a simulation based on the total number of room visits (instead of direct patient contacts only). The alternative normal risk simulation resulted in 44,173 CEs over the course of 1 million NDCs, resulting in 83 episodes of hospital-acquired MRSA colonization and 27 episodes of MRSA infection (Table 4). The mean cost of MRSA infection was $57,442 (95% CI, $23,299–$91,585). The median cost of MRSA infection was $30,458 (IQR, $23,291–52,615). The mean cost per NDC in the alternative normal risk model was thus $1.55 (95% CI, $0.47–$2.63).

Secondary Analysis

The simulation results were applied to a hypothetical 200-bed hospital. A 200-bed hospital at 85% occupancy provides care for approximately 62,050 patient-days per year. Each patient-day involves 32.27 direct patient contacts with 55.13% hand hygiene compliance, resulting in 14.50 NDCs per patient-day, or 899,581 annual NDCs per 200-bed facility. This translates to an estimated 37.8 hospital-acquired MRSA infections annually and an annual cost related to hospital-acquired MRSA infection of $1,779,283 (95% CI, $1,231,160–$2,378,120). Increasing hand hygiene compliance by 1% resulted in a decrease of annual NDCs by 20,046, prevention of 0.84 MRSA infection, and a mean decrease in expected MRSA-related costs of $39,650 (95% CI, $18,286–$61,014). A 5% improvement in hand hygiene compliance resulted in a decrease of annual NDCs by 100,232, prevention of 4.21 MRSA infections, and a mean decrease in expected MRSA-related costs of $198,250 (95% CI, $91,429–$305,072).

TABLE 4. Results of Normal Risk, High-Risk, and Alternative Normal Risk Simulations

Result	Normal risk scenario[a]	High-risk scenario[b]	Alternative model[c]
Noncompliant events	1,000,000	1,000,000	1,000,000
Contaminated encounters	44,284	953,912	44,173
MRSA colonizations	143	3340	83
MRSA infections	42	980	27
Cost of MRSA infection, $			
Mean (95% CI)	47,092 (26,040–68,146)	53,598 (50,098–57,097)	57,442 (23,299–91,585)
Median (IQR)	22,353 (17,006–42,996)	35,045 (18,106–72,022)	30,458 (23,291–52,615)
Cost per noncompliant event, $ (95% CI)	1.98 (0.91–3.04)	52.53 (47.73–57.32)	1.55 (0.47–2.63)

NOTE. CI, confidence interval; IQR, interquartile range; MRSA, methicillin-resistant *Staphylococcus aureus.*
[a] Hand hygiene noncompliance by a healthcare worker between contact with 2 patients of unknown MRSA colonization status.
[b] Hand hygiene noncompliance between contact with 2 patients by a healthcare worker during which patient 1 was colonized or infected with MRSA and the MRSA status of patient 2 was unknown.
[c] Simulation based on total room visits instead of on direct patient contacts only.

DISCUSSION

Infections are spread to patients in the hospital primarily by means of the hands of healthcare workers. Typically, this occurs when healthcare workers neglect to perform hand hygiene before patient contact. This study quantified the cost associated with a single episode of hand hygiene noncompliance. Costs ranged from approximately $2 (when a patient's MRSA colonization or infection status was unknown) to more than $50 per episode (when healthcare workers did not wash their hands after contact with a patient who was an MRSA carrier). On the basis of these estimates, improved hand hygiene compliance among healthcare workers in a 200-bed hospital by as little as 1% would prevent approximately 1 episode of infection due to MRSA and would result in MRSA prevention–associated cost savings of almost $40,000 per year. If the same hospital improved hand hygiene compliance by 5%, approximately 4 MRSA infections would be prevented and the cost savings would approach $200,000.

The findings from this study represent a departure from the conventional method of analyzing costs associated with hospital-acquired infection. Historically, costs have been estimated as a function of number and types of infection.[2,4,20-22] Unfortunately, since the transmission of pathogens in the hospital occurs silently, it is impossible to attribute an incident of hospital transmission of a pathogen or the resulting hospital-acquired infection to the behaviors of an individual healthcare worker. Because of this inability to attribute causality to a healthcare worker's actions, it is difficult to make healthcare workers accountable for the occurrence of hospital-acquired infections. Costs presented on a "per infection" basis seem abstract to many clinicians and often are ineffective in generating accountability for behavior and improving compliance among healthcare workers. Conversely, presenting cost as a function of compliance with process (such as hand hygiene) is more relevant and tangible to healthcare workers and, we believe, can be used to elicit greater accountability for and ownership of suboptimal hand hygiene practices.

This study also presented an additional model that accounted for the possibility that a healthcare worker could transfer MRSA from 1 patient to a second patient during a room visit, even if the healthcare worker had contact only with the room environment but no direct contact with the second patient. In this alternative simulation, the cost associated with each episode of hand hygiene noncompliance was $1.55.

Several assumptions were made to make the model practical and clinically useful. First, we assumed steady state MRSA prevalence. In reality, MRSA prevalence is likely fluid and has been increasing over time.[25] We believe, however, that in a short-run experiment the assumption of stable prevalence is reasonable. While short-term fluctuations in MRSA prevalence have not been examined, we believe these fluctuations to be the result of infection outbreaks resulting in increased, rather than decreased, prevalence. Given the likelihood of MRSA prevalence to increase over time and as a result of nonzero probability of the occurrence of an MRSA outbreak, it is likely that the study results represent an underestimate of the actual cost of hand hygiene noncompliance. Second, we assumed that all MRSA transmission in the hospital resulted from hand hygiene noncompliance. While data show that hand hygiene noncompliance is the leading cause of hospital-acquired MRSA infection,[7] there are other causes of transmission as well, such as contaminated shared equipment. To the extent that other causes account for hospital-acquired MRSA infection, our results may represent an overestimate of NDC cost. In addition, the model assumed rates of hand hygiene compliance among healthcare workers that were based on published US data.[26] If higher rates of compliance had been included in the model, the resulting number of MRSA infections and MRSA-associated costs would have been smaller. The model also did not account for the proportion of healthcare workers who might be chronic carriers of MRSA (4.6% of healthcare workers, according to 1 study).[27] Finally, some might consider the mean cost per MRSA infection (approximately $50,000) used in the model to be too high, although we used mean and median values from published literature. In addition, some reports have noted that after patients become colonized with MRSA during hospitalization almost 50% of MRSA infections occurred after discharge,[28] and some of these postdischarge infections would not have been accounted for in this model. Thus, MRSA infection–related costs in this model might have been underestimated. Furthermore, even if the cost used in modeling had been as low as one-half the mean value used (approximately $25,000 per MRSA infection), the annual MRSA infection–related expenses attributable to hand hygiene noncompliance accrued by a 200-bed hospital would still have been substantial (approximately $500,000).

Each NDC represented a single episode of hand hygiene noncompliance. Ergo, we assumed that each iteration involved compliant hand hygiene prior to contact with the first patient. We did not account for the possibility that healthcare workers who are habitually noncompliant may have a much higher incidence and burden of contamination or colonization with MRSA. While it is likely that a disproportionate number of transmissions are caused by such a group of habitually noncompliant individuals, the results are averaged over the entire population of healthcare workers. Therefore, we assume that all healthcare workers exhibit the same compliance rate. Again, we believe that this simplification causes our model to underestimate actual costs, because habitually noncompliant workers will display a higher transmission rate resulting from multiple consecutive NDCs. In addition, during the study period it was the policy at Duke University Medical Center to use contact precautions (gowns and gloves for all healthcare workers entering the room) for patients known to be infected or colonized with MRSA for the duration of the hospitalization. The association between the use of contact precautions and the number of direct contacts was

not studied at Duke during the study period and thus was not incorporated into the model.

Costs associated with hand hygiene noncompliance were limited exclusively to nosocomial MRSA transmission and infection. Many other pathogens are also spread to patients on the hands of healthcare workers as a result of noncompliance with hand hygiene. In fact, in some reports MRSA accounts for fewer than 8% of all hospital-acquired infections.[29] Because our model focused on costs associated only with MRSA transmission, it substantially underestimated the costs associated with hand hygiene noncompliance. To form a more complete and accurate estimate of the costs associated with hand hygiene noncompliance, additional analyses should be conducted that focus on costs associated with hospital transmission of other pathogens in addition to MRSA.

Poor practices among healthcare workers lead to patient harm. Unfortunately, these poor practices occur frequently in the hospital. Noncompliance with hand hygiene places patients at unnecessary risk for colonization with and subsequent infection by multidrug-resistant pathogens, such as MRSA. Despite the well-publicized fact that MRSA leads to poor outcomes and increased cost for patients, most hand hygiene campaigns fail to lead to sustained improvements in hand hygiene compliance. This study provides a relatively conservative (yet still alarming) estimate of the financial impact of a single incident of hand hygiene noncompliance and also provides an estimate of the aggregate costs imparted by noncompliance with hand hygiene for a typical US hospital. The results from this study can be used to attribute cost to and improve accountability for suboptimal healthcare worker behaviors. In addition, these results provide cost estimates that can be used to model the cost-effectiveness of hand hygiene interventions and may give hospitals and organizations the incentive to invest in novel and effective methods and technologies for improving the hand hygiene culture, habits, and compliance of healthcare workers.

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Potential conflicts of interest. K.S.K. has served as a consultant for Schering-Plough and Ortho McNeil and is a member of the speakers' bureaus for Cubist, Pfizer, Merck, Schering-Plough, and Wyeth Ayerst. D.J.A. has received research grants (unrelated to the present project) from Merck and from Pfizer. All other authors report no conflicts of interest relevant to this article.

Address reprint requests to Keith S. Kaye, MD, MPH, 3990 John R, Detroit, MI 27710 (kkaye@dmc.org).

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Major article

Comparative efficacy of commercially available alcohol-based hand rubs and World Health Organization-recommended hand rubs: Formulation matters

Sarah L. Edmonds MS [a,*], David R. Macinga PhD [a], Patricia Mays-Suko BS [b], Collette Duley BS [b], Joseph Rutter BS [a], William R. Jarvis MD [c], James W. Arbogast PhD [a]

[a] *Research and Development, GOJO Industries, Akron, OH*
[b] *BioScience Laboratories, Inc, Bozeman, MT*
[c] *Jason and Jarvis Associates, LLC, Hilton Head, SC*

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Background: Use of alcohol-based hand rubs (ABHRs) effectively reduces transmission of pathogenic microorganisms. However, the impact of alcohol concentration and format on product efficacy is currently being debated.

Methods: Two novel ABHR formulations containing 70% ethanol were evaluated according to American Society for Testing and Materials E1174 (Health Care Personnel Handwash [HCPHW]) and European Norm (EN) 1500 global standards. Additionally, using E1174, the efficacy of these formulations was compared head-to-head against 7 representative commercially available ABHRs and 2 World Health Organization recommended formulations containing alcohol concentrations of 60% to 90%.

Results: The novel ABHR formulations met efficacy requirements for both HCPHW and EN 1500 when tested at application volumes typically used in these methods. Moreover, these formulations met HCPHW requirements when tested at a more realistic 2-mL product application. In contrast, the commercial ABHRs and World Health Organization formulations failed to meet HCPHW requirements using a 2-mL application. Importantly, product performance did not correlate with alcohol concentration.

Conclusion: Product formulation can greatly influence the overall antimicrobial efficacy of ABHRs and is a more important factor than alcohol concentration alone. Two novel ABHRs based on 70% ethanol have been formulated to meet global efficacy standards when tested at volumes more representative of normal product use in health care environments.

Hand hygiene is the most important intervention to prevent the transmission of pathogenic microorganisms and has been shown to reduce infection rates,[1-3] even among high-risk patient populations.[4-7] Alcohol-based hand rubs (ABHRs) reduce hand contamination during routine patient care more effectively than handwashing with soap and water.[8-11] In addition, using ABHRs is more convenient, less time-consuming, and less irritating than washing with soap and water.[12-14] The use of ABHRs in health care settings has been associated with reduced transmission of pathogens and reduced hospital-acquired infection rates,[15-17] including those caused by methicillin-resistant *Staphylococcus aureus* (MRSA).[18-22]

The Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) promote the use of ABHRs containing 60% to 95% alcohol as the standard of care for hand hygiene practice in health care settings when hands are not visibly soiled.[23,24] To assist countries and health care facilities in the adoption of ABHRs, the WHO has created relatively simple formulation recipes for local preparation, particularly for developing countries, where suitable commercial products may be unavailable or unaffordable.[24] One formulation contains 80% ethanol volume per volume (vol/vol) and the other contains 75% isopropyl alcohol (vol/vol).

In the CDC guidelines, it is stated that antiseptic hand hygiene products intended for use by health care workers in the United States are regulated by the Food and Drug Administration (FDA), and requirements for testing of health care worker handwash products are outlined by the FDA Tentative Final Monograph for Healthcare Antiseptic Drug Products.[23] Because of the magnitude of

* Address correspondence to Sarah L. Edmonds, MS, PO Box 991, Akron, OH 44309.
E-mail address: edmondss@gojo.com (S.L. Edmonds).

Conflicts of interest: S.L.E., D.R.M., J.R., and J.W.A. are full-time employees of GOJO Industries. W.R.J. is a consultant to GOJO, BD, J&J, and Teleflex.

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Table 1
Summary of test products used in this series of studies

Code	Test product name	Manufacturer	Active ingredient	Format
A	PURELL Advanced Instant Hand Sanitizer	GOJO Industries	70% Ethanol (vol/vol)	Gel
B	PURELL Advanced Instant Hand Sanitizer Foam	GOJO Industries	70% Ethanol (vol/vol)	Foam
C	PURELL Green Certified Instant Hand Sanitizer	GOJO Industries	70% Ethanol (vol/vol)	Gel
D	Sterillium Comfort Gel	Bode Chemie Hamburg	90% Ethanol (vol/vol) 85% ethanol (wt/wt)*	Gel
E	WHO-recommended hand rub formulation with ethanol	n/a	80% Ethanol (vol/vol)	Rinse
F	WHO-recommended hand rub formulation with isopropanol	n/a	75% Isopropanol (vol/vol)	Rinse
G	Endure 320 Advanced Care Waterless Antimicrobial Hand Rinse with Moisturizer	Ecolab	62% Ethanol (vol/vol)	Gel
H	Avagard Foam Instant Hand Antiseptic with Moisturizers	3M	70% Ethanol (vol/vol) 62% ethanol (wt/wt)*	Foam
I	Avagard D	3M	68% Ethanol (vol/vol) 61% ethanol (wt/wt)*	Gel
J	Alcare OR Foamed Antiseptic Hand Rub	Steris	62% Ethanol (vol/vol)	Foam
K	Rio Gel Antiseptico	Rioquímica	70% Ethanol (vol/vol)	Gel
L	Cutan Alcohol Foam Antiseptic Handrub	DEB	60% Ethanol (vol/vol)	Foam

*Ethanol concentration on product label is reported as weight per weight (wt/wt); (vol/vol) concentration was determined analytically in the authors' laboratory.

effort and inherent challenges to conducting controlled clinical studies to demonstrate clinical effectiveness of ABHRs, in vivo laboratory studies using human subjects are used to determine their antimicrobial efficacy and serve as surrogates for clinical effectiveness.[12] In the United States, the Health Care Personnel Hand Wash (HCPHW) method, which is synonymous with American Society for Testing and Materials (ASTM) E1174, is used.[25] In the European Union, the hygienic hand rub method, European Norm (EN) 1500, is used.[26] Although both methods are intended to measure the reduction of transient challenge bacteria by ABHRs, the methodologic details differ significantly. ASTM E1174 utilizes *Serratia marcescens* as the challenge organism, and the test product is evaluated after both a single use and repeated use. The US FDA requires that products achieve at least a 2-$\log_{10}$ reduction of the marker organism after the first application and a 3-$\log_{10}$ reduction after the tenth and final application.[25] EN 1500 utilizes *Escherichia coli* as the challenge organism, and the test product is evaluated against a reference ABHR (60% isopropyl alcohol [vol/vol], applied in 2 applications of 3 mL for 30 seconds each) using a crossover design. To meet the requirements of the European norm, the $\log_{10}$ reduction for the test formulation must not be significantly inferior to those observed for the reference solution.[26] Given the differences between the ASTM E1174 and EN 1500 methodologies and requirements, ABHRs that meet one standard may not necessarily meet the other standard.

Despite the long-standing conclusion that ethanol concentrations ranging from 60% to 95% are safe and effective for routine hand antisepsis[24,25,27,28] and numerous reports demonstrating that ABHRs reduce infection rates in clinical settings,[15-18] recent studies have questioned the efficacy of gel and foam ABHRs, particularly those containing <75% alcohol.[29-32] These studies have concluded that both alcohol concentration and product format (ie, gel, foam, or rinse) are critical determinants of ABHR efficacy. However, because such studies have not separated these and other interdependent variables, and in some instances have modified the test methods, drawing valid conclusions by interpreting the results is difficult.[29-32]

To address the questions that have been raised regarding the influence of alcohol concentration and product format on ABHR efficacy, a series of studies was conducted to determine the ability of novel 70% ethanol gel and foam ABHR formulations to meet global in vivo efficacy standards. Furthermore, to understand better the relative influence of alcohol concentration, product format, and total product formulation on ABHR efficacy, these formulations were compared with several ABHR formulations containing alcohol concentrations ranging from 60% to 90%.

METHODS

Test products

Twelve ABHR formulations were evaluated (Table 1). Marketed products were acquired through normal sales and distribution channels. The WHO formulations were prepared based on the specifications provided in the WHO guidelines.[24] A 70% ethanol-in-water control and vehicle controls (all ingredients except the 70% ethanol) were prepared for products A and B.

In vitro time-kill experiment

In vitro time-kill suspension tests were performed as described in ASTM E2783-10.[33] The challenge bacteria were *S marcescens* (ATCC No. 14756) or MRSA (ATCC No. 33591). Test samples were evaluated at 99% concentration using a 10-mL total reaction volume and a 15-second contact time. Immediately following the 15-second contact time, the test samples were neutralized and diluted in Butterfield's buffered phosphate solution with lecithin and polysorbate-80 as product neutralizers (or BBP+). Colonies were enumerated on tryptic soy agar with product neutralizers (or TSA+).

In vivo methodologies

EN 1500

Studies were conducted as described in the EN 1500 standard.[26] The subjects' hands were washed with soft soap, dried, and then immersed to the midmetacarpals in a broth culture of *E coli* (K12 NCTC 10538) for 5 seconds. Excess fluid was drained, and the hands air-dried for 3 minutes. The fingertips were rubbed for 60 seconds on the bottom of a Petri dish containing tryptic soy broth to obtain prevalues, and then dilutions were prepared and plated onto TSA. The hands were allowed to dry, and then either 3 mL of the test product was applied for 30 seconds or 2 applications comprising 3 mL (6 mL total) of the reference solution (60% isopropyl alcohol [vol/vol]) was applied for 30 seconds each (60 seconds total) using a crossover design. At the end of the prescribed contact time, the fingers were rinsed in tap water for 5 seconds to stop the reaction. Fingertips were again rubbed in a Petri dish containing tryptic soy broth with neutralizer to obtain postdisinfection values, and then dilutions were prepared and plated onto TSA. For each subject, the entire procedure was then repeated using the product not used during the first application procedure (ie, either the test product or reference solution). Colony counts were performed after 24 and 48

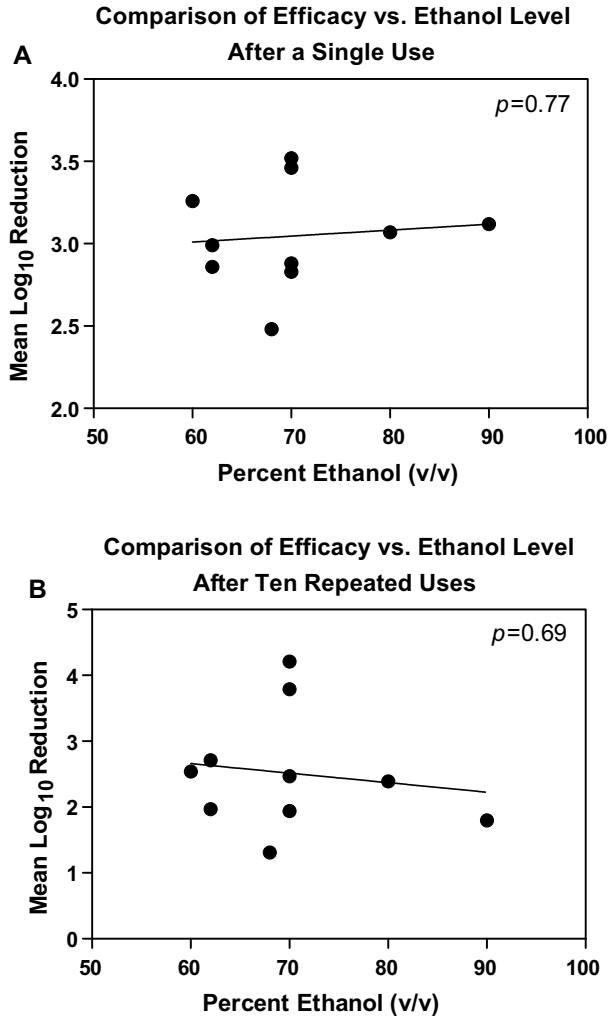

Fig 1. ABHR efficacy according to ASTM E1174 plotted against ethanol concentration after (A) a single product application and (B) 10 product applications for the 10 ethanol-based hand rub formulations shown in Table 3.

hours of incubation at 36°C. Log_{10} reductions were calculated, and test products were compared with the reference product using a Wilcoxon matched-pairs signed-ranks test. Test products that demonstrated log_{10} reductions significantly less than that observed with the reference solution were classified as not meeting the norm. Twenty subjects completed evaluations for products A and B, and 15 subjects completed evaluations for product C.

HCPHW

Studies were conducted as described in ASTM E1174-94.[34] Institutional Review Board approval was obtained prior to enrolling study subjects who were at least 18 years of age, of mixed sex and race. All subjects' hands were free from disorders that could have compromised the subject and the study. Subjects refrained from use of antimicrobials for 7 days prior to the study. A 30-second handwash using nonmedicated soap and a 30-second rinse were performed to remove dirt and oil from the subjects' hands. Hands were contaminated with a total volume of 5 mL of a suspension of *S marcescens* (ATCC No. 14756), transferred into each subject's hands in 3 aliquots (1.5, 1.5, and 2 mL), and spread over all surfaces of the hands for 45 seconds following each aliquot. After a timed

Table 2
Efficacy of three 70% ethanol ABHRs evaluated according to EN 1500

Test product code	Mean log_{10} reduction (95% CI) product*	Mean log_{10} reduction (95% CI) reference†	Difference	*P* value
A	5.25 (4.78-5.72)	5.11 (4.79-5.43)	0.14	Not significant
B	5.06 (4.57-5.55)	5.11 (4.79-5.43)	−0.05	Not significant
C	5.17 (4.74-5.60)	4.80 (4.31-5.29)	0.37	Not significant

CI, Confidence interval.
*Three milliliters of test product applied for 30 seconds.
†Three milliliters of reference applied for 30 seconds followed by an additional 3 mL of reference applied for 30 seconds.

Table 3
Log_{10} reductions obtained using an in vitro time-kill method with a 15-second contact time against *S marcescens* and MRSA

		Log_{10} reductions in 15 seconds	
Test product code	Sample description	*S marcescens* (ATCC No. 14756)	MRSA (ATCC No. 33591)
A	As manufactured	≥5.8	≥5.8
	Vehicle (no ethanol)	0.6	0.6
B	As manufactured	≥4.7	≥4.2
	Vehicle (no ethanol)	0.1	0.0
Active control	70% ethanol in water	≥4.7	≥4.2

NOTE. The "≥" symbol indicates complete kill at the limit of detection.

2-minute air-dry, the glove juice sampling procedure was performed. It was followed with a 30-second handwash using nonmedicated soap and a 30-second rinse. This first contamination cycle provided the baseline population level. The hand contamination was repeated 10 times, each followed by product application with a randomly assigned test product. Test products were evaluated using an application volume of 2 mL (with the exception of the first study, in which products were evaluated using an application volume of 5 mL) and were rubbed on the hands until dry. Microbial samples were taken using the glove juice sampling procedure after product applications 1, 3, 7, and 10. Following the glove juice procedure, an aliquot was removed, diluted in BBP+, and plated onto TSA+. Plates were incubated at 25°C for approximately 48 hours, red colonies were counted, and log_{10} reductions were calculated. A neutralizer assay was conducted according to ASTM E1054-08 demonstrating the test products were effectively neutralized by the neutralization procedure (data not shown).[35]

The following number of subjects completed the studies: 8 subjects used products A and B, and 24 subjects used product C for the first study; 24 subjects used products A and B for the second study; and 12 subjects used products A through L for the final study. Statistical comparisons between products were made for the data shown in the first study using a 1-way analysis of variance and, for data in the final study, using a 2-way analysis of variance whereby $\alpha = .05$. For data shown in Figure 1, linear regression analysis was applied to determine the relationship between ethanol concentration and log_{10} reductions. If a significantly nonzero slope resulted ($P < .05$), then the relationship was considered significant.

RESULTS

Table 2 demonstrates that ABHR gel and foam formulations containing 70% ethanol are capable of meeting EN 1500 efficacy requirements. All test products were statistically noninferior to the isopropyl alcohol reference.

To determine whether ABHR gel and foam formulations containing 70% ethanol are capable of meeting FDA HCPHW

Table 4
Comparative efficacy of ABHRs evaluated according to ASTM E1174

Test product code	Study No.*	Test product description	Application 1 $\log_{10}$ reduction (95% CI)	Application 10 $\log_{10}$ reduction (95% CI)	Meets US FDA requirements
A	1	70% Vol/vol ethanol gel	3.58 (3.34-3.82)	3.50 (3.26-3.74)	Yes
	2		3.35 (3.14-3.56)	4.09 (3.78-4.40)	Yes
B	1	70% Vol/vol ethanol foam	3.55 (3.32-3.74)	4.00 (3.26-4.24)	Yes
	2		3.48 (3.34-3.61)	4.41 (4.14-4.69)	Yes
D	1	90% Vol/vol ethanol gel	3.12 (2.89-3.35)	1.80 (1.57-2.63)	No
E	1	80% Vol/vol ethanol rinse	3.07 (2.84-3.29)	2.39 (2.17-2.61)	No
F	1	75% Vol/vol isopropanol rinse	3.12 (2.88-3.36)	2.03 (1.80-2.27)	No
G	2	62% Vol/vol ethanol gel	2.99 (2.77-3.21)	1.97 (1.75-2.19)	No
H	2	70% Vol/vol ethanol foam	2.83 (2.61-3.05)	1.94 (1.72-2.16)	No
I	2	68% Vol/vol ethanol gel	2.48 (2.26-2.70)	1.31 (1.09-1.53)	No
J	2	62% Vol/vol ethanol foam	2.86 (2.64-3.08)	2.71 (2.49-2.93)	No
K	2	70% Vol/vol ethanol gel	2.88 (2.66-3.10)	2.47 (2.25-2.69)	No
L	2	60% Vol/vol ethanol foam	3.26 (3.04-3.48)	2.54 (2.32-2.76)	No

CI, Confidence interval.
*Data are from 2 separate studies.

requirements, a study was conducted using ASTM E1174 with an application volume of 5 mL. Products A, B, and C achieved $\log_{10}$ reductions (95% confidence interval) of 3.94 (3.62-4.26), 4.14 (3.80-4.49), and 4.22 (3.93-4.50), respectively, after the first application and 5.47 (5.17-5.76), 5.45 (5.23-5.67), and 3.32 (2.97-3.66), respectively, after the tenth application. All test products met FDA HCPHW requirements for a 2-$\log_{10}$ reduction after the first application and a 3-$\log_{10}$ reduction after the tenth application. The $\log_{10}$ reductions for products A and B were significantly greater than the $\log_{10}$ reductions produced by product C after the tenth application ($P < .0001$).

A second E 1174 study was conducted to measure the efficacy of the novel 70% ethanol products, A and B, using an application volume of 2 mL, which is a more realistic volume used by health care workers. Products A and B achieved $\log_{10}$ reductions (95% confidence intervals) of 3.20 (3.04-3.37) and 3.62 (3.48-3.77), respectively, after the first application and 3.60 (3.37-3.82) and 4.06 (3.84-4.28), respectively, after 10 consecutive applications. Both products met FDA HCPHW requirements.

In vitro time-kill experiments were then performed to determine whether excipient ingredients in test products A and B contribute to their bactericidal activity. As illustrated in Table 3, products A and B and the ethanol-in-water control inactivated S marcescens and MRSA below the limit of detection in 15 seconds. In contrast, vehicle controls without ethanol did not exhibit significant bactericidal activity against the test organisms. These results demonstrate that ethanol is the active ingredient in products A and B.

Products A and B were then compared with representative ABHR formulations containing ethanol concentrations ranging from 60% to 90% tested according to ASTM E1174 (Table 4). Products A and B met FDA HCPHW requirements after both 1 application and 10 applications. Log_{10} reductions achieved by the comparative test products (D through L) declined from the first application to the tenth application, and all failed to achieve a 3-$\log_{10}$ reduction at the tenth application. Furthermore, product A produced statistically significant greater bacterial reduction than products G through K ($P < .05$), and product B had significantly greater bacterial reduction than products H through K ($P < .05$) at application 1. After 10 applications, products A and B were statistically superior to all other formulations tested ($P < .001$). To understand the relative contribution of alcohol concentration and product formulation on efficacy by ASTM E1174, $\log_{10}$ reductions were plotted against alcohol concentration for each test product (Fig 1). No significant relationship was found between ethanol concentration and ABHR efficacy after a single application ($P = .77$) or after 10 repeated applications ($P = .69$).

DISCUSSION

In contrast to conclusions from previous reports, our data demonstrate that, when properly formulated, ABHRs containing 70% alcohol are capable of meeting global efficacy standards. Moreover, simply including alcohol at a concentration >75% will not guarantee that an ABHR formulation will meet global efficacy standards. These results highlight the importance of the total ABHR formulation in determining in vivo efficacy, particularly under high-frequency use. Excipient ingredients may either negatively or positively influence the antimicrobial properties of the alcohol. The importance of total product formulation is clearly demonstrated by the data in Table 4. The novel 70% ethanol gel and foam ABHR (products A and B) met FDA requirements when tested using a realistic application volume, whereas test products containing the identical level of ethanol (H and K) did not meet efficacy requirements and were statistically inferior to A and B in reducing bacterial contamination. Furthermore, products D through F were statistically inferior to products A and B and failed to meet FDA efficacy requirements after 10 applications despite containing higher levels of alcohol.

Varying the alcohol concentration within the range considered safe and effective by the FDA (60%-95%) had very little influence on product efficacy (Fig 1). In fact, product D, which is based on 90% ethanol (vol/vol), achieved the second lowest $\log_{10}$ reduction at the tenth application. This result is not surprising because others have reported that solutions containing concentrations of alcohol >90% are, in fact, less potent because proteins are not denatured easily in the absence of water.[36] In addition, others have reported that the activity of alcoholic solutions begins to decline when concentrations are >80%.[24]

Contrary to previous reports concluding that the efficacy of gel and foam ABHRs is inferior to that of ABHR rinses, the current studies demonstrate that product format does not have a major impact on efficacy. Test products A (gel) and B (foam) were statistically equivalent to each other and to the WHO recommended rinses (E and F) after a single use and statistically superior to products E and F after multiple uses. The efficacy of test products D through L, ranging in alcohol content from 60% to 90%, and representing rinse, foam, and gel formats were all similar after a single application (Table 4). Therefore, making broad assumptions about efficacy based on the format of a product is ill-advised.

Although the mechanism by which products A and B are able to significantly outperform other ABHRs is unclear, preliminary data suggest that excipient ingredients in the formulations enable alcohol to more efficiently disrupt bacterial membrane integrity

(unpublished data). However, as illustrated in Table 3, these excipient ingredients do not possess significant antimicrobial activity, and ethanol serves as the sole active ingredient in these formulations.

The primary limitation of these studies is that they utilize standard ASTM and EN test methods, both of which serve as surrogates for clinical effectiveness. The success criteria have been set somewhat arbitrarily and have not been demonstrated to correlate with clinical effectiveness.[22,37-39] Both the CDC and WHO have noted the shortcomings of the current methods and have emphasized a need to develop better in vivo test methods.[23,24] Future studies should be conducted to document and quantify the clinical effectiveness of various ABHRs taking into account product formulation, application volumes, and health care worker compliance. Such studies should include formulations that perform differently in standardized in vivo efficacy methods. The best ABHRs will be those that achieve at least a threshold of antimicrobial efficacy while optimizing product acceptance to ensure maximum usage (ie, hand hygiene compliance).

In conclusion, these studies collectively demonstrate that gel and foam are reliable formats for a novel 70% ethanol formulation that meets global efficacy standards when used at volumes that more accurately reflect use in clinical settings. Our results demonstrate the importance of careful ingredient selection and proper formulation when developing ABHRs to maximize antimicrobial efficacy. Finally, product format and alcohol content (within the range of 60%-95% [vol/vol]) are not the key drivers of product efficacy.

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Best Practices for Healthy Hands

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Hand Hygiene and Skin Health

Hand hygiene is a critical aspect of patient safety.[1] Repeated use of alcohol-based hand rub (ABHR) and soap and water places healthcare workers (HCWs) at increased risk for skin damage, and skin irritation is often cited as a barrier to hand hygiene compliance.[2] Lack of awareness of the true causes of skin damage is a significant contributing factor. Therefore, to maintain healthy hands and ensure hand hygiene compliance, it is essential that HCWs understand the behaviors that actually lead to skin damage and steps they can take for prevention.

Common Myths About ABHR Among Healthcare Workers

MYTH Soap and water is gentler on my skin.

TRUTH Over-use of soap and water causes damage to the outermost layer of the skin by dissolving lipids that help retain the skin's moisture, leading to dry, flakey skin. With each soap and water use, the problem worsens. Eventually, nerves in the skin become exposed, and when ABHR is applied, there is stinging and burning. Because of this, HCWs often continue soap and water use, creating a cycle of skin damage that is difficult to interrupt.

MYTH ABHRs damage my skin.

TRUTH ABHRs have very little impact on the skin. ABHR can cause stinging and burning when hands are already damaged, usually from over-use of soap and water. Imagine applying ABHR to your hand when you have a paper-cut. The ABHR burns, but it did not cause the paper cut.

MYTH *vs.* TRUTH

MYTH Soap and water works better than ABHR.

TRUTH National and international hand hygiene guidelines recommend using ABHR as the preferred means of cleaning hands. ABHR has been very well-studied and has superior efficacy over soap and water (even antimicrobial soap). In addition, ABHR has many other benefits like speed of use, convenience and skin health.[1,3]

MYTH After every 3-5 ABHR uses, I should wash my hands with soap & water.

TRUTH This is not necessary. When ABHRs were first introduced to the market, manufacturers recommended washing after every 3-5 uses; however, formulations have evolved and this is no longer recommended. If product build-up develops, it can be washed off, although it is best to reserve soap and water for when absolutely necessary, like when hands have visible blood or bodily fluids on them.

Warning Signs of Skin Damage

Your hands are your most important tool. Always be on the lookout for skin damage.

Early Warning Signs of Skin Damage:

Dryness, tightness, flaking or itching of the knuckles, back of hands, and between fingers.

What To Do:

Make sure you're using ABHR as much as possible and not over-washing with soap and water. Use a lotion as often as possible during your shift and get a thicker lotion or cream for frequent use at home.

Advanced Signs of Skin Damage:

Damage that involves the palms of the hands, redness, swelling, blistering, bleeding, cracking, difficulty making a fist.

What To Do:

Find out who to report the damage to at your facility and seek help right away.

There are two types of skin reactions related to hand hygiene:

Irritant Contact Dermatitis

Most common type of skin reaction associated with hand hygiene. Symptoms can include dryness, irritation, itching, cracking, and when severe, bleeding. In one study, **85%** of nurses reported a history of irritant contact dermatitis, and **25%** reported dermatitis symptoms at the time of the study.[4]

Allergic Contact Dermatitis

Rare type of skin reaction that results from an allergy to an ingredient in the hand hygiene product. Can be mild and localized, or severe and generalized. It is sometimes difficult to distinguish from irritant contact dermatitis and may warrant evaluation by a dermatologist.

Quick Tips for Healthy Skin

1. Always choose ABHR over soap and water, unless your hands are visibly soiled, after caring for patients with *Clostridioides difficile* (C. diff) or per your facility's policy.
2. Make lotion a part of your routine all year round. Be aware of times when you may need to increase the use of lotion or use a thicker moisturizer at home.
3. Be on the lookout for skin damage. The earlier you recognize it and do something about it, the better. Seek help immediately if your skin damage is advanced. Find out who you need to notify at your facility.

Lotion is Essential

Incorporating lotion into your routine is good practice all of the time, but especially:

- During cold, dry weather or changes in climate
- When you're switching from one hand hygiene product to another
- If your hands feel dry for any reason

AT WORK

- Ideally, use lotion after every soap and water use
- At minimum, apply twice per shift

Never bring lotions from home into the clinical environment without approval. Non-approved lotions may not be compatible with other hand hygiene products and gloves and may have levels of fragrance that are not appropriate.

AT HOME

- Apply lotion as frequently as possible
- Apply a thicker lotion or cream before going to sleep so it remains on the skin for an extended period

Thicker lotions and creams have a higher oil content and can be very beneficial outside of work when more greasiness can be tolerated. Look for a thicker lotion or cream that is fragrance-free for use at home.

Which Product Should I Use?

USE SOAP AND WATER:

- When hands are visibly dirty or contaminated with proteinaceous material or are visibly soiled with blood or other body fluids
- Before eating
- After using the restroom
- After caring for patients with C. diff if your policy requires it

USE ABHR:

- If hands are not visibly soiled
- Before direct patient contact
- After removing gloves
- Before handling an invasive device for insertion
- After contact with intact skin
- Before moving from contaminated patient body site to a clean site during patient care
- After contact with inanimate objects or medical equipment close to a patient

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GOJO Industries, Inc.
One GOJO Plaza, Suite 500
P.O. Box 991 • Akron, OH 44309-0991 • USA
Tel: 1-330-255-6000 • Toll-free: 1-800-321-9647
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How Hand Hygiene Dispenser Data Can Impact Productivity, Waste, and Satisfaction

Case Study

GOJO partnered with Crothall Healthcare and Altavita Village in Riverside, California to conduct a case study on the implementation of PURELL SMARTLINK™ Service Alerts in a healthcare facility. GOJO provided the SMARTLINK technology during the trial period.

Length of Study

A 10-month study was conducted to determine how hand hygiene dispenser data can impact productivity (labor servicing time of hand hygiene dispensers), refill consumable waste and facility staff satisfaction.

Size of Study

The study was completed at Altavita's Continuing Care Retirement Community with a cleaning staff of 34 people. SMARTLINK enabled dispensers were installed throughout the Skilled Nursing unit of the facility, which equated to almost 100 dispensers – a mix of PURELL® Hand Sanitizer and P ROVON® Soap dispensers. A cleaning staff of 3 was dedicated to servicing the unit.

Measurements Taken

Dispenser Service Time

The first step of the study was to validate the accuracy of the system by comparing the data received from the SMARTLINK System to each dispenser's refill level. All dispensers were initially serviced by the cleaning staff. Each dispenser was opened and checked during the morning shift and when they received complaints from facility staff.

The second step of the study was to repurpose workflow. A designated person was assigned daily to manage the consumables and address all of the alerts and alarms. The rest of the cleaning staff was then redirected to focus only on cleaning and to no longer touch the dispensers in the resident rooms and other assigned areas of the facility. Each morning a report was printed with the location and type of refills that required replacement. The staff member responsible for refills saved the time it would have taken to open each dispenser, visually estimate the refill level and walk to an inventory closet to get a refill replace replacement.

Refill Replacement Timing

At the onset of the study, partially filled refills identified before an evening or weekend shift would be replaced to ensure product was available when service staff was limited. As the service team modified workflow, became more confident in the data and learned exactly when to change the refill, the accuracy of refill replacement began to improve. By the end of the study, the Environmental Services (EVS) team had determined the exact product percentage level to replace refills in the facility to ensure product availability, and to provide the lean evening and weekend staff with a report of the refill locations and types that would need changed. This significantly reduced the amount of waste on a monthly basis, and had a positive impact on consumable cost reduction.

Altavita Village | Purell® SMARTLINK™

Staff Complaints

Before the study, EVS staff would receive occasional complaints about a dispenser outage or dispenser not working properly. After the implementation of this system, the data they received on a daily basis, allowed the EVS staff to pinpoint the exact problem or need of a dispenser and proactively service it to avoid empty or non-working dispensers. This often minimized the amount of time that staff had to change workflow to wash or sanitize.

Results

31 % Reduction in Labor Time

- Dispenser touchpoints were completely eliminated for the cleaning staff and reduced by 88% for the individual designated to service dispensers.

- The facility was able to reduce service staff in the unit to 2.5 FTE's. The 0.5 FTE's labor time savings equated to over 30 hours per week, and allowed EVS to reallocate that time to servicing other areas of the facility.

14 % Reduction in Consumable Costs

- Initially, the data enabled the reduction of one refill a month. By the end of the study, this facility saw a 14% reduction in dispenser refill waste and overall refill spend.

100 % Reduction in Complaints

- Replacing refills and servicing dispensers at the right time completely eliminated complaints from staff in the unit.

- "As a whole, the industry is reliant on staff to make a judgment call on whether or not to replace soap and hand sanitizer. Is it enough to make it through the evening, or even the rest of the shift? Often the answer is to err on the side of caution and replace it, because the alternative will lead to outage and complaints. So do you replace before it is necessary, thus eliminating the possibility of outage, but then creating unnecessary waste? This system eliminates the need to rely on housekeeper's judgment, and allows the manager to decide when to replace. It eliminates complaints and gives you more control."

Lee Van Den Bossche Director of Environmental Services Altavita Village

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GOJO Industries, Inc.
One GOJO Plaza, Suite 500
P.O. Box 991 • Akron, OH 44309-0991
Tel: 1-330-255-6000 • Toll-free: 1-800-321-9647
Fax: 1-800-FAX-GOJO

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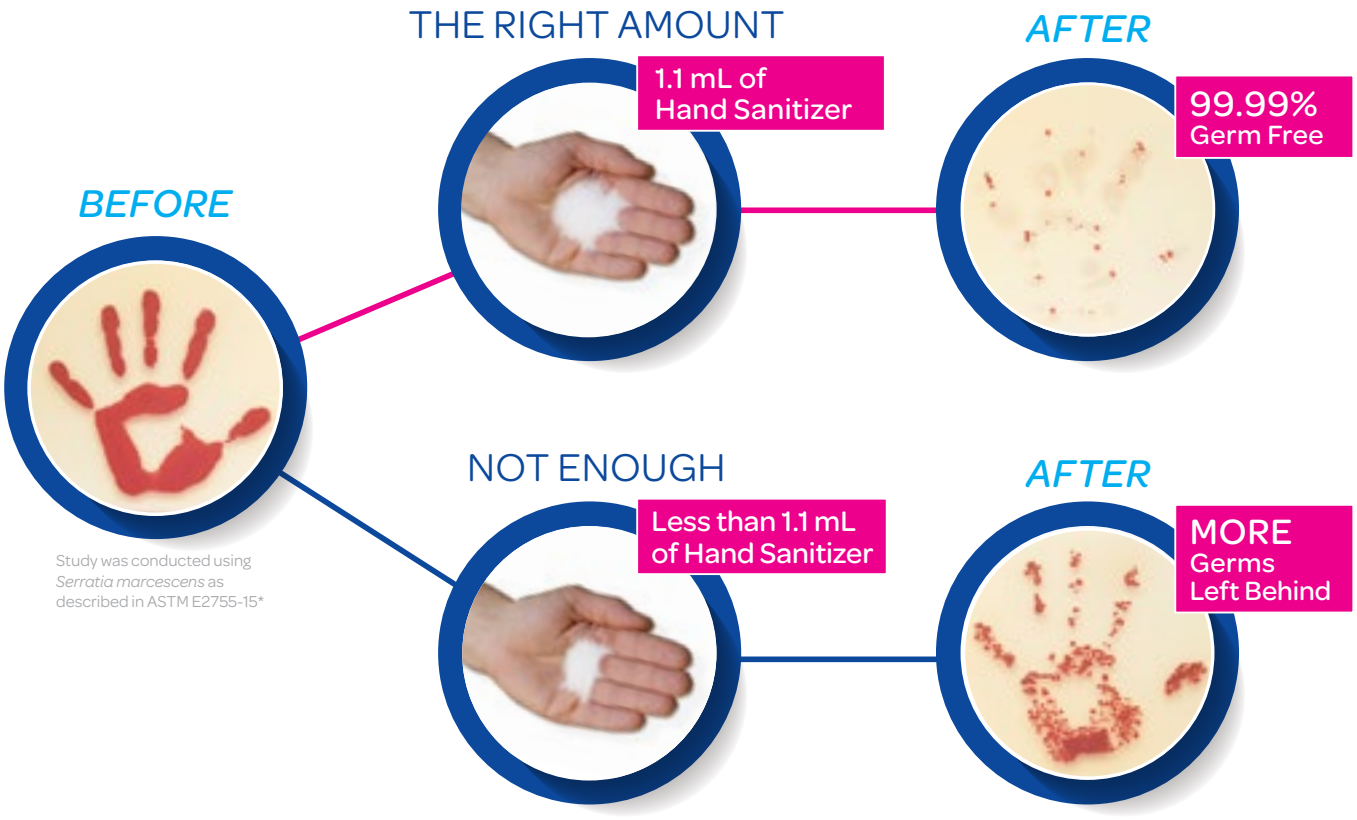

Study was conducted using *Serratia marcescens* as described in ASTM E2755-15*

*ASTM E2755-15, Standard Test Method for Determining the Bacteria-Eliminating Effectiveness of Healthcare Personnel Hand Rub Formulations Using Hands of Adults, ASTM International, West Conshohocken, PA, 2015, www.astm.org

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