ORIGINAL ARTICLE

Hand Hygiene With Alcohol-Based Hand Rub: How Long Is Long Enough?

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BACKGROUND. Hand hygiene is the core element of infection prevention and control. The optimal hand-hygiene gesture, however, remains poorly defined.

OBJECTIVE. We aimed to evaluate the influence of hand-rubbing duration on the reduction of bacterial counts on the hands of healthcare personnel (HCP).

METHODS. We performed an experimental study based on the European Norm 1500. Hand rubbing was performed for 10, 15, 20, 30, 45, or 60 seconds, according to the WHO technique using 3 mL alcohol-based hand rub. Hand contamination with *E. coli* ATCC 10536 was followed by hand rubbing and sampling. A generalized linear mixed model with a random effect on the subject adjusted for hand size and gender was used to analyze the reduction in bacterial counts after each hand-rubbing action. In addition, hand-rubbing durations of 15 and 30 seconds were compared to assert non-inferiority (0.6 $\log_{10}$).

RESULTS. In total, 32 HCP performed 123 trials. All durations of hand rubbing led to significant reductions in bacterial counts ($P < .001$). Reductions achieved after 10, 15, or 20 seconds of hand rubbing were not significantly different from those obtained after 30 seconds. The mean bacterial reduction after 15 seconds of hand rubbing was 0.11 $\log_{10}$ lower (95% CI, −0.46 to 0.24) than after 30 seconds, demonstrating non-inferiority.

CONCLUSIONS. Hand rubbing for 15 seconds was not inferior to 30 seconds in reducing bacterial counts on hands under the described experimental conditions. There was no gain in reducing bacterial counts from hand rubbing longer than 30 seconds. Further studies are needed to assess the clinical significance of our findings.

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Hand hygiene is the core element of infection prevention; it is the most important preventive measure against healthcare associated infection (HAI) and the spread of antimicrobial resistance.[1] In this context, alcohol-based hand rubs (ABHRs) constitute the most effective agents to avoid bacterial cross-transmission via hands of healthcare personnel (HCP).[1,2] Great efforts have been made to improve hand-hygiene compliance among HCP worldwide.[2,3] However, less attention has been devoted to the quality of the hand-hygiene action itself, despite this aspect likely being equally important in preventing HAI.[4]

The World Health Organization (WHO) hand-hygiene guidelines[1] address several aspects related to the quality of the hand-hygiene action. A specific 6-step technique has been recommended via the "How to Hand Rub" poster. However, less precise information exists on the volume of ABHR (ie, "a palmful") and duration of hand rubbing (ie, 20–30 seconds) required to perform an optimal hand-hygiene action.[1,5] Furthermore, compliance with these recommendations remains suboptimal among HCP.[6,7]

According to recently published studies, both the hand-hygiene technique[8,9] and volume of ABHR used[10] are major determinants of the antimicrobial efficacy of hand-hygiene actions. However, the optimal duration of hand rubbing remains to be determined. Indeed, no strong evidence has been provided to support the WHO 20–30-second recommendation[1] for hand rubbing duration. This question is clinically relevant because lack of time is repeatedly identified as a major factor negatively influencing adherence to hand hygiene.[11] Therefore, recommendations for shorter durations of hand rubbing could potentially lead to improved compliance.

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The objective of the current study was to evaluate the effect of hand-rubbing duration on the antimicrobial efficacy of hand hygiene. We aimed to determine whether a shorter duration of hand rubbing could have efficacy similar to that of the currently recommended standard of 30 seconds.

METHODS

Study Setting, Participants, and Eligibility Criteria

Healthcare personnel (HCP) with extensive training and expertise in hand hygiene were enrolled in an experimental study at the microbiology laboratory of the Infection Control Program, University of Geneva Hospitals (HUG) and Faculty of Medicine.

Participants were required to have short fingernails (<1 mm). Exclusion criteria included the presence of artificial fingernails or skin disorders. All subjects gave informed consent to participate.

Study Design

We performed a laboratory-based experimental study using the European Norm (EN) 1500.[10,12] The study consisted of 2 experiments. In the first set of trials (experiment 1), we explored the effect of different hand-rubbing durations (ie, 10, 15, 20, 30, 45 and 60 seconds) in reducing bacterial counts on HCP hands. In a second set of trials (experiment 2), we tested the hypothesis that hand rubbing for 15 seconds was not inferior to hand rubbing for 30 seconds in terms of bacterial reduction on hands.

Briefly, each trial consisted of a sequence of contamination of HCP hands with *E. coli* (artificial contamination), hand rubbing for a defined duration, and immediate sampling of hands (microbiological sampling). Baseline assessments were performed only once in each experimental session by sampling HCP hands immediately after contamination with *E. coli*. The microbiological sampling was performed using the fingertips method.[10,12]

Artificial Contamination

The reference strain *E. coli* ATCC 10536 was used to prepare a homogeneous bacterial suspension of approximately 10^8 colonies forming units per milliliter (cfu/mL). Prior to each contamination procedure, participants were asked to thoroughly wash their hands with 5 mL non-antimicrobial liquid soap. Participants inserted their hands up to the metacarpals into the bacterial suspension for 5 seconds and then let their hands air dry for 3 minutes.

Hand Rubbing With Different Durations of Hand Friction

Regardless of the specific duration tested, hand rubbing was performed in each trial according to the WHO "How to Hand Rub" technique using 3 mL isopropanol 60% (v/v; ie, EN 1500 reference standard).[12] The order of the performance of the different hand-rubbing durations was randomly assigned in both experiments.

In the first set of trials (experiment 1), all HCP were asked to follow the WHO "How to Hand Rub" technique. In the second set of trials (experiment 2), to ensure hand-rubbing technique homogeneity, participants were instructed and trained to repeat each step of the WHO technique twice when hand rubbing for 15 seconds and 5 times when hand rubbing for 30 seconds. Thus, participants performed standardized varying repetitions of each individual step of the WHO technique, depending on the duration of hand rubbing.

Microbiological Sampling

At baseline and immediately after each hand-rubbing sequence, bacteria were recovered from HCP hands using the fingertips method.[10,12] This procedure consisted of rubbing the 5 fingertips of the dominant hand placed in a sterile dish containing tryptone soy broth (TSB) for 1 minute. In trials of experiment 1, 10 mL TSB was used as recommended by EN 1500.[12]

Even though EN 1500[12] states that isopropanol 60% (v/v) is neutralized by dilution only and does not recommend the use of an inhibitor in the TSB sampling medium, we wanted to ensure that the additional isopropanol 60% (v/v) potentially remaining on HCP hands (particularly following shorter hand rubbing, ie, 15 seconds) would not inhibit *E. coli* growth. Thus, in trials of experiment 2, participants performed the fingertips method in a larger sterile dish containing 100 mL of TSB to obtain a 10-times more diluted isopropanol on the TSB medium than that recommended by EN 1500.

Plating of Samples

Samples were studied in 4 different dilutions (10^{-1} to 10^{-4}) to accurately estimate bacterial counts within each sample. A 1-mL sample of each dilution was spread over the surface of a TSB agar plate and subsequently incubated at 36°C ± 1°C for 48 h. *Escherichia coli* bacterial colony-forming units were quantified by visual inspection, adjusted for the corresponding dilution factor, and converted to $\log_{10}$.

Study Outcomes and Statistical Analysis

The primary outcome in both experiments was the difference in $\log_{10}$ cfu of *E. coli* recovered from HCP hands between baseline and after each of the hand-rubbing sequences studied, corresponding to a reduction of bacterial counts. Hand-rubbing duration (10, 15, 20, 30, 45 and 60 seconds) was the main predictor. We used a generalized linear mixed model with a random effect on the subject to analyze the results. We also assessed whether the effect of hand-rubbing duration differed according to hand size category by testing the interaction between these 2 variables. Hand surface areas were

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calculated and categorized as small (surface area ≤375 cm^2), medium (376–424 cm^2), or large (≥425 cm^2).[10,13] The final model was adjusted for hand size and gender. The reduction of bacterial counts on HCP hands between baseline and each of the hand-rubbing sequences studied was also compared with the reduction achieved after 30 seconds of hand rubbing, which was considered the reference.

Additionally, we assessed whether the reduction of $\log_{10}$ cfu achieved after 15 seconds of hand rubbing was inferior to that achieved after 30 seconds. We prespecified that a maximum 0.6 $\log_{10}$ difference between the 2 durations would be considered the margin of non-inferiority based on EN 1500.[12]

Statistical analyses were performed using Stata version 14 (StataCorp, College Station TX). Statistical significance was defined as $P < .05$ (2-sided).

RESULTS

In total, 32 HCP participated in the experiments. Among the participants, 22 were female (68.6%); 10 (31.3%) were medical doctors, 17 (53.1%) were nurses, and 5 (15.6%) were in other healthcare professions. The mean hand surface area was 396.9 cm^2 (standard deviation [SD], 53.7; median, 397). In addition, 9 subjects (28.1%) had small hands, 15 (46.7%) had medium-sized hands, and 7 (21.9%) had large hands.[10,13]

In total, 23 HCP participated in 87 trials of experiment 1. The total *E. coli* counts on HCP hands at baseline and after each hand-rubbing duration are listed in Table 1. After adjustment for gender and hand size, duration of hand rubbing was significantly associated with bacterial counts on hands ($P < .001$). Compared to baseline values, the mean bacterial count reduction was −2.27 $\log_{10}$ (95% confidence interval [CI], −2.99 to −1.54) after 10 seconds; −2.52 $\log_{10}$ (95% CI, −2.93 to −2.10) after 15 seconds; −2.69 $\log_{10}$ (95% CI, −3.16 to −2.23) after 20 seconds; −2.70 $\log_{10}$ (95% CI, −3.11 to −2.28) after 30 seconds; −2.17 $\log_{10}$ (95% CI, −2.71 to −1.62) after 45 seconds and −2.26 $\log_{10}$ (95% CI, −2.80 to −1.71) after 60 seconds (Figure 1). The reduction of bacterial count after hand rubbing for 30 seconds was not statistically different from that obtained after 10, 15, or 20 seconds (Table 2). Moreover, the reduction in bacterial count after 30 seconds of hand rubbing was significantly higher than that achieved after 45 or 60 seconds (Table 2). There was no correlation between hand size and hand rubbing duration ($P = .989$).

In total, 18 subjects were enrolled in 36 trials in experiment 2. All participants performed 15 and 30 seconds of hand rubbing. The mean total *E. coli* count on HCP hands at baseline was 6.1 $\log_{10}$ (SD, ± 0.62; median, 6.15); it was 3.28 $\log_{10}$ (SD, ± 1.04; median, 3.35) after 15 seconds of hand rubbing and 3.17 $\log_{10}$ (SD, ± 1.07; median, 3.2) after 30 seconds of hand rubbing. After adjustment for gender and hand size, duration of hand rubbing was significantly associated with bacterial counts on hands ($P < .001$). Compared to baseline values, the mean

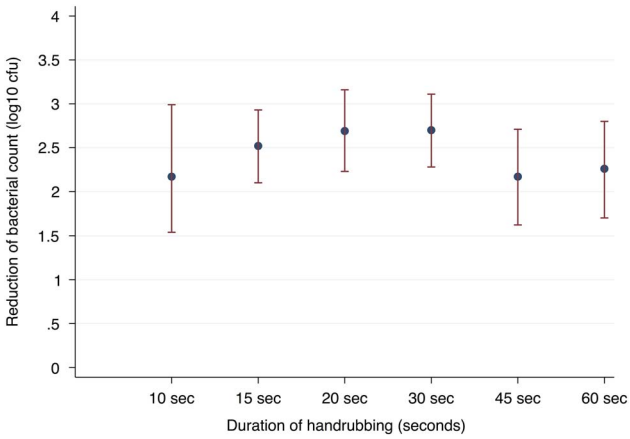

FIGURE 1. Bacterial count reduction ($\log_{10}$) from baseline across 6 durations of hand rubbing (mean and 95% CI). Alcohol-based hand rub was isopropanol 60% (v/v), 3 mL, according to EN 1500. Abbreviations: cfu, colony-forming units; CI, confidence interval.

TABLE 1. Bacterial Counts ($\log_{10}$) on HCP Hands at Baseline and Following Different Durations of Rubbing with Alcohol-Based Hand Rub[a]

	Bacterial Count ($\log_{10}$), mean (± SD, median)						
Variable	Baseline (n = 23)	10 sec (n = 5)	15 sec (n = 23)	20 sec (n = 16)	30 sec (n = 23)	45 sec (n = 10)	60 sec (n = 10)
Overall	6.1 (±0.82, 6.4)	3.7 (±0.4, 3.8)	3.6 (±0.9, 3.5)	3.5 (±1.3, 3.3)	3.4 (±1.1, 3.1)	3.7 (±0.7, 3.8)	3.6 (±0.7, 3.9)
By hand size							
Small	5.7 (±1.1, 6.3)	3.9 (±0.2, 4.0)	3.1 (±0.7, 3.0)	2.8 (±0.7, 3.0)	2.9 (±0.8, 2.6)	3.1 (±0.6, 3.0)	3.1 (±0.6, 3.2)
Medium	6.2 (±0.7, 6.5)	3.4 (±0.6, 3.4)	3.7 (±0.9, 3.7)	3.6 (±1.7, 3.3)	3.4 (±1.1, 3.5)	3.8 (±0.6, 3.9)	3.7 (±0.8, 4.0)
Large	6.6 (±0.3, 6.6)	…	4.1 (±1.0, 4.2)	4.2 (±0.7, 4.3)	4.1 (±1.3, 4.4)	4.6 (±0.5, 4.6)	4.4 (±0.4, 4.4)

NOTE. HCP, healthcare personnel; SD, standard deviation.

[a]Alcohol-based hand rub used was isopropanol 60% (v/v), 3 mL, according to EN 1500.

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TABLE 2. Bacterial Count Reduction (log_{10}) From Baseline Across 6 Durations of Hand Rubbing[a]

Duration of Rubbing	B Coefficient	95% Confidence Interval	*P* Value
Reference (30 sec)			<.001
10 sec	−0.45	−1.09 to +0.19	.174
15 sec	−0.18	−0.53 to +0.17	.312
20 sec	+0.07	−0.33 to +0.47	.720
45 sec	−0.71	−1.19 to −0.23	.004
60 sec	−0.62	−1.10 to −0.14	.011

[a]Alcohol-based hand rub used was isopropanol 60% (v/v), 3 mL, according to European Norm 1500, with 30 seconds as the reference after adjustment for gender and hand size using multivariate analysis from a mixed linear model with a random effect on the intercept (standard deviation ± 0.98 around the intercept).

bacterial count reduction was −2.85 log_{10} (95% CI, −3.25 to −2.45) after 15 seconds and −2.96 log_{10} (95% CI, −3.36 to −2.56) after 30 seconds. The reduction in bacterial count was not significantly different between 30 seconds and 15 seconds after adjustment for gender and hand size ($P = .532$). The mean bacterial count reduction after 15 seconds of hand rubbing was 0.11 log_{10} (95% CI, −0.46 to 0.24) lower than after 30 seconds of hand rubbing. Using the prespecified −0.6 log_{10} non-inferiority margin, 15 seconds of hand rubbing was not inferior to 30 seconds with regard to bacterial count reductions.

DISCUSSION

Even though compelling evidence shows that inadequate performance of the hand-hygiene action can lead to cross-transmission of bacteria,[1,8] it still receives little attention in most healthcare institutions.[4] Contributing factors may include the lack of clear evidence-based guidance on its performance and the absence of tool to conduct monitoring and foster its improvement among HCP.

In the current study, we investigated the influence of hand-rubbing duration on the reduction of bacterial counts on HCP hands. In the first experiment, we observed that the reduction of bacterial count after hand rubbing for 15 or 20 seconds was not significantly different from that achieved after 30 seconds. In the second experiment, we demonstrated that performing hand rubbing for 15 seconds was not inferior to 30 seconds, while controlling for possible confounders. Our results expand and strengthen the findings of previous studies. Dharan et al[14] showed that a 15-second application of different ABHRs on fingertips was not significantly different from a 30-second application in terms of bacterial reduction. Sickbert-Bennett et al[15] studied the microbiological efficacy of 10 seconds of hand rubbing with different hand-hygiene agents according to the ASTM-E-1174-94 test method, but the absence of comparison with other durations of hand rubbing made it difficult to draw conclusions. Our study, performed in conditions closely mimicking clinical practice, controlling for the hand-hygiene technique and the volume of ABHR used and testing different durations of hand rubbing, provides more meaningful data for the understanding of the effect of hand-rubbing duration on the antimicrobial efficacy of hand-hygiene action.

The recommendations of the WHO hand-hygiene guidelines regarding the volume of ABHR to use in each hand hygiene action and duration of hand rubbing are somewhat incomplete. It states: "Apply a palmful of ABHR and cover all surfaces of the hands. Rub hands until dry." Additionally, the WHO "How to Hand Rub" poster indicates that the duration of the hand hygiene procedure should be 20 to 30 seconds.[1,5] The Centers for Disease Control and Prevention (CDC) guidelines for hand hygiene[16] are equally imprecise, mentioning, "If hands are dry before 10 to 15 seconds, an insufficient amount of ABHR has been used." Furthermore, the European Norm[12] to test hand products also includes 30 seconds of hand rubbing, but ABHRs can be tested with hand-rubbing durations of up to 60 seconds to satisfy the norm.[17–19] These heterogeneous and imprecise recommendations reflect the overall poor level of evidence and lack of consensus.

As part of a randomized controlled trial, Reilly et al[9] asked HCP in clinical wards to perform the WHO 6-step hand-hygiene technique using 3 mL ABHR and found that the median hand-rubbing duration was 43 seconds (95% CI, 39–45). The real duration of hand rubbing practiced by HCP in routine care remains largely unknown, but it is certainly less (mean 11.6 seconds [SD ±0.7], according to Sickbert-Bennett et al[15]). HCP and infection control practitioners would certainly welcome recommendations of shorter durations of hand rubbing because lack of time remains one of the most important barriers to good practices.[11] In fact, a balance is needed between the optimal performance of the hand-hygiene action and its feasibility in daily routine. Although our results demonstrate that hand rubbing for 15 seconds provides similar microbiological efficacy to that achieved after 30 seconds, these results were obtained using 3 mL ABHR and performing the WHO 6-step technique of hand rubbing and in laboratory-based experimental conditions involving HCP with extensive training and expertise in hand hygiene. This experimental setting emphasizes the importance of coaching HCPs in the performance of the hand-hygiene action using an integrated approach of its 3 main aspects: technique, volume of ABHR, and duration of hand rubbing. In fact, the volume of ABHR[10,20–22] and the technique of hand rubbing[7] are also critical determinants of the antimicrobial efficacy of the hand-hygiene action. Our results may allow the future endorsement of a shorter, more feasible and evidence-based duration of hand rubbing, moving forward from the concept of "rubbing hands until dry."

Regarding the rather vague concept of "rubbing hands until dry," which is endorsed by both WHO and CDC guidelines, we believe that it may lead HCPs to use low volumes of ABHR to obtain dry hands within 20–30 seconds (or even less) of hand rubbing. Indeed, time to dry depends on the volume, type, and alcohol concentration of ABHR used.[17] Our group has

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previously observed that the perception of dry hands in 30 seconds was only achieved in 1 of 15 volunteers using 2 mL ABHR and that this number increased to 13 of 15 when using 1 mL ABHR.[18] These findings were confirmed by others also showed that low volumes that dry at 30 seconds fail to pass the EN 1500 norm.[17,19] Indeed, 1 mL seems to be the average volume of ABHR used in routine care,[23] and this volume is clearly insufficient for an optimal hand-hygiene procedure.[10,17,19]

Interestingly, hand rubbing for 45 or 60 seconds was associated with somewhat lower antimicrobial efficacy when compared to hand rubbing for 30 seconds. We have no clear explanation for this result, but we hypothesize that it could be due to the desquamation of the stratum layer of the skin during hand rubbing, leading to a loss of effectiveness in alcohol-induced bacterial killing. Possible additional explanations cannot be proposed in the light of our results.

Given that the results of experiment 2 confirmed those obtained in experiment 1, we are confident of the absence of any significant residual alcohol activity on hands after hand rubbing and of an effect on bacterial counts. According to Rotter,[24] the minimal bactericidal concentration (MBC) for isopropanol against *E. coli* at 1 minute in contact suspension tests is 26% (v/v). Even in the most extreme scenario where all 3 mL isopropanol 60% (v/v) applied on HCP hands for hand rubbing would be transferred to the TSB, which is very unlikely considering the volume of ABHR spread on hands during hand-hygiene action, we obtained maximal final isopropanol concentrations of 17% (v/v) in 10 mL TSB and 1.7% (v/v) in 100 mL of TSB, respectively. Both concentrations are thus below the MBC for *E. coli*.

Our study has several limitations. First, this is a laboratory-based experimental study that only tested the ABHR and strain used in the EN 1500. More studies with different bacteria and types of ABHRs are needed to further validate these results. Furthermore, the methodology used in experiment 2 to standardize the WHO 6-step technique does not reflect daily clinical practice. Importantly, a consensus has not been reached regarding the clinical significance of the observed differences in bacterial reduction achieved with the different durations of hand rubbing. While bacterial reduction was not statistically different between 15, 20, and 30 seconds, we cannot exclude a type II error. Finally, it was not our intention to change the recommendations regarding the necessary duration of hand rubbing of individual ABHRs, as those should be tested according to the appropriate norms. Our results suggest, however, that norm-testing standards should be revisited and should include evaluation of hand-rubbing durations as short as 15 seconds.

In conclusion, our results suggest that, under the described experimental conditions, using 3 ml of ABHR and performing the WHO "How to Hand Rub" technique, hand rubbing for 15 seconds is not inferior to 30 seconds in reducing bacterial counts on HCP hands. Furthermore, no gain seems to result from performing hand rubbing for longer than 30 seconds.

These results have important implications for hand-hygiene practices and future research. Reducing the time needed to perform an optimal hand hygiene gesture could lead to augmented hand-hygiene compliance, as lack of time is a major factor affecting non-compliance.[11] Further studies are needed to assess the clinical significance of our findings. More attention is needed to the quality of hand-hygiene action. Furthermore, an evidence-based consensus should be reached to permit the creation of tools to monitor and improve it.

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