Infection Control & Hospital Epidemiology (2019), **40**, 1248–1252
doi:10.1017/ice.2019.251

Original Article

Nursing preference for alcohol-based hand rub volume

Richard A. Martinello MD[1,3], James W. Arbogast PhD[2], Kerri Guercia MT[3], Albert E. Parker PhD[4] and John M. Boyce MD[5]

[1]Yale School of Medicine, New Haven, Connecticut, [2]GOJO Industries, Akron, Ohio, [3]Yale New Haven Hospital, New Haven, Connecticut, [4]Center for Biofilm Engineering and Department of Mathematical Sciences, Montana State University, Bozeman, Montana and [5]J.M. Boyce Consulting, Middletown, Connecticut

Abstract

Background: The effectiveness of alcohol-based hand rub (ABHR) is correlated with drying time, which depends on the volume applied. Evidence suggests that there is considerable variation in the amount of ABHR used by healthcare providers.

Objective: We sought to identify the volume of ABHR preferred for use by nurses.

Methods: A prospective observation study was performed in 8 units at a tertiary-care hospital. Nurses were provided pocket-sized ABHR bottles with caps to record each bottle opening. Nurses were instructed to use the volume of ABHR they felt was best. The average ABHR volume used per hand hygiene event was calculated using cap data and changes in bottle mass.

Results: In total, 53 nurses participated and 140 nurse shifts were analyzed. The average ABHR dose was 1.09 mL. This value was greater for non-ICU nurses (1.18 mL) than ICU nurses (0.96 mL), but this difference was not significant. We detected no significant association between hand surface area and preferred average dose volume. The ABHR dose volume was 0.006 mL less per use as the number of applications per shift increased ($P = .007$).

Conclusions: The average dose of ABHR used was similar to the dose provided by the hospital's automated dispensers, which deliver 1.1 mL per dose. The volume of ABHR dose was inversely correlated with the number of applications of ABHR per shift and was not correlated with hand size. Further research to understand differences and drivers of ABHR volume preferences and whether automated ABHR dosing may create a risk for people with larger hands is warranted.

(Received 20 February 2019; accepted 20 May 2019; electronically published 19 September 2019)

The effectiveness of alcohol-based hand rub (ABHR) is known to be closely correlated with the amount of time it takes for the product to dry on the hands (ie, drying time), which depends primarily on the volume applied.[1,2] One recent study found a linear relationship between drying time and the log reduction of bacteria on hands that was independent of application volume.[3] Limited evidence suggests that there is considerable variation in the amount of ABHR used per application by healthcare providers. This variability in volume applied may be due to dispenser malfunction or, more likely, user preference.[4–6] A recent study found that healthcare professionals (HCPs) frequently applied amounts of ABHR that took <5 seconds to <15 seconds to dry, which also suggests that the volume of ABHR applied was quite variable.[7] Some HCPs believe that the amount delivered by some dispensers is excessive and takes too long to dry, and as a result, they apply doses lower than recommended.[2,5,8] This issue is pertinent because application of small amounts of ABHR may not be sufficient to cover all surfaces of the hands and reduce bacteria on hands to the degree recommended by regulatory agencies.[9–12] We sought to identify the volume of ABHR used by nurses.

Methods

A prospective, observational study was conducted in the inpatient setting at a single, large, academic medical center. Nurses working in 8 hospital units (5 adult and pediatric inpatient wards and 3 intensive care units) were invited to participate in the study. All participating nurses were providing hands-on patient care. Nurses who volunteered to participate were each given pocket-sized, 125-mL ABHR bottles with a flip-top electronic memory cap that recorded the number of times the bottle was opened. It utilized a proprietary custom cap that employed magnetic detection and recorded events to a nonvolatile memory (see US patent no. 9580210 for more detail). Nurses were instructed in the safe use of these personal ABHR bottles to prevent cross contamination. The ABHR product used was a commercially available gel containing 70% ethanol. A similar product was used in the hospital but was dispensed as a foam rather than as a gel. Each unit was observed on 3 separate days. During each shift, nurses were instructed to use ABHR from the electronic-cap bottle for all hand hygiene opportunities where they would normally use ABHR. The electronic cap recorded the number of bottle openings. Nurses were repeatedly instructed to use the volume

Author for correspondence: Richard A. Martinello, MD, Yale School of Medicine, Department of Internal Medicine (Infectious Diseases), 20 York Street, New Haven, CT 06510. Email: Richard.Martinello@yale.edu

Cite this article: Martinello RA, *et al.* (2019). Nursing preference for alcohol-based hand rub volume. *Infection Control & Hospital Epidemiology*, 40: 1248–1252, https://doi.org/10.1017/ice.2019.251

© 2019 by The Society for Healthcare Epidemiology of America. All rights reserved.

https://doi.org/10.1017/ice.2019.251 Published online by Cambridge University Press

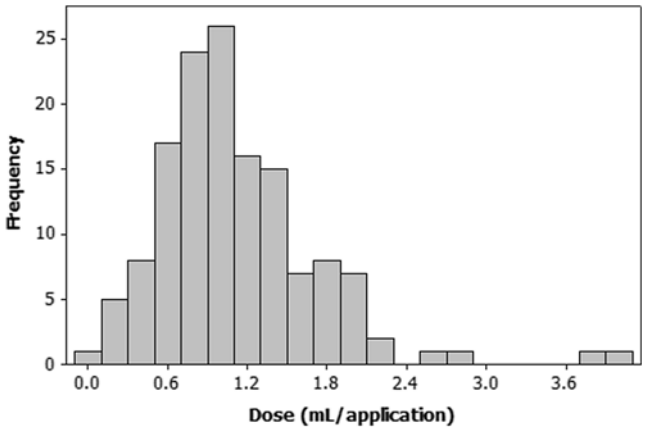


Fig. 1. Frequency histogram of the mean number of alcohol-based hand rub (ABHR) doses by nursing shift.

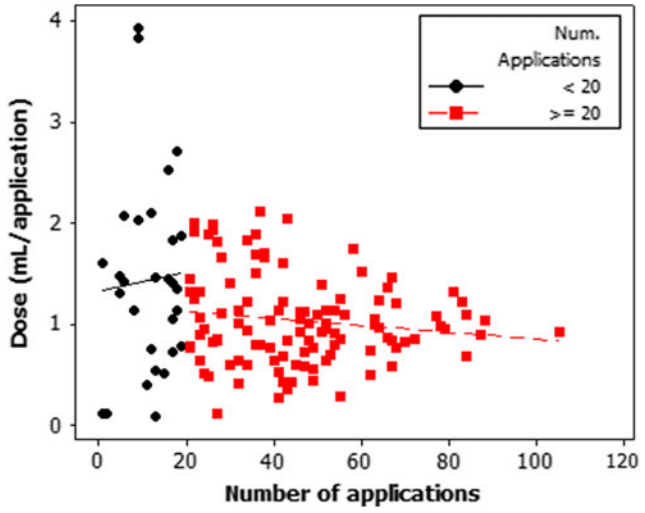


Fig. 2. Dose volume as a function of the number of alcohol-based hand rub (ABHR) uses per nursing shift.

of ABHR they felt was best and were blind to the objectives of the study.

At the beginning of each shift, each nurse was provided with a new electronic cap bottle containing 125 mL ABHR. The bottles were collected at the end of the shift after use. The mass of ABHR used from each bottle was determined by weighing each bottle before and after use by nurses, and the number of uses was collected from the electronic cap at the end of each shift. The volume (mL) of ABHR used from each bottle was calculated by dividing the mass of ABHR used by the density of the product (0.8698 gm/mL). For each nurse, the average volume of ABHR used per application was calculated by dividing the volume used from each bottle by the number of times the electronic bottle cap had been opened.

Participants' hand surface area was estimated using a validated method as an average of both left and right hands.[13] Hand sizes were classified as either small (≤375 cm^2), medium (375–424 cm^2), or large (≥425 cm^2).[11]

A brief, self-administered survey was distributed and collected from all study participants. The survey obtained 9-point Likert-

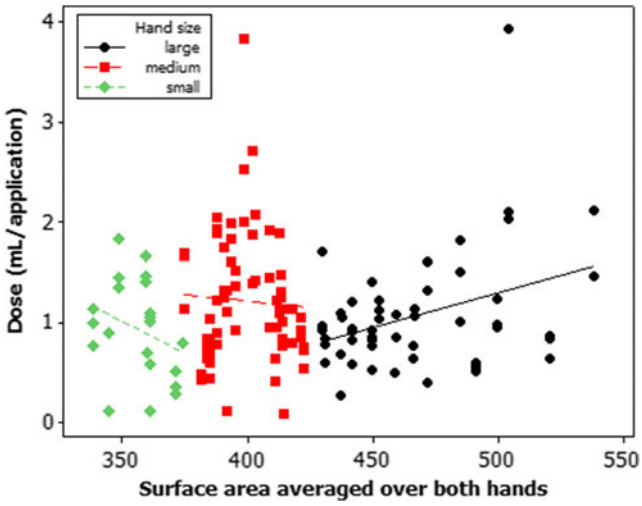


Fig. 3. Dose as a function of the nurse participants' hand surface area (cm^2). Hand size is classified as small (≤375 cm^2), medium (375 – 424 cm^2), or large (≥425 cm^2). The line represents the correlation between mean dose and hand size by hand surface-area strata.

scale responses regarding subject perception of the ABHR, and open-ended questions were used to collect participants' thoughts regarding the appropriate volume of ABHR, ABHR drying time, and the participants' understanding of the rationale for recommended ABHR volume and use.

Statistical analysis

Linear mixed-effects models were used to analyze the dose volumes with a random effect for nurses that accounted for the repeated doses measured on different days from the same nurse; and a second random effect for unit that accounted for the possible correlation among nurses who work in the same hospital unit. Covariates for hand surface area and the number of applications were included. Fixed effects were also included to compare doses between ICUs versus non-ICUs and to compare doses among small, medium, and large hand sizes.

The investigation was approved by the Yale Human Investigations Committee.

Results

In total, 53 nurses participated in the study, with 5–13 nurses from each of 8 hospital units. Two units were ICUs and employed 22 (42%) of the 53 participating nurses. Each nurse participated in the study 1–3 days, for a total of 140 nurse shifts of ABHR use, and 7 nurse shifts were excluded because the electronic devices used to count ABHR uses malfunctioned. Furthermore, 74% of volunteers provided 3 shifts of ABHR use data. The overall average volume ABHR used was 1.09 mL per application (standard deviation [SD], 0.61 mL). The middle 95% ranged from 0.19 to 2.34 mL (Fig. 1). The average hand surface area was 417 cm^2 (SD, 46 cm^2): 9 (17%) participants had small hands, 24 (45%) had medium-sized hands, and 20 (38%) participants had large hands. We detected a statistically significant negative correlation ($P = .007$) between dose volume and the number of applications (Fig. 2) even though the ABHR dose volume decreased by only 0.006 mL per use (SD, ± 0.002 mL) as the number of applications increased (based on a mixed-effects regression of dose volume vs number of applications). We found no significant correlation

https://doi.org/10.1017/ice.2019.251 Published online by Cambridge University Press

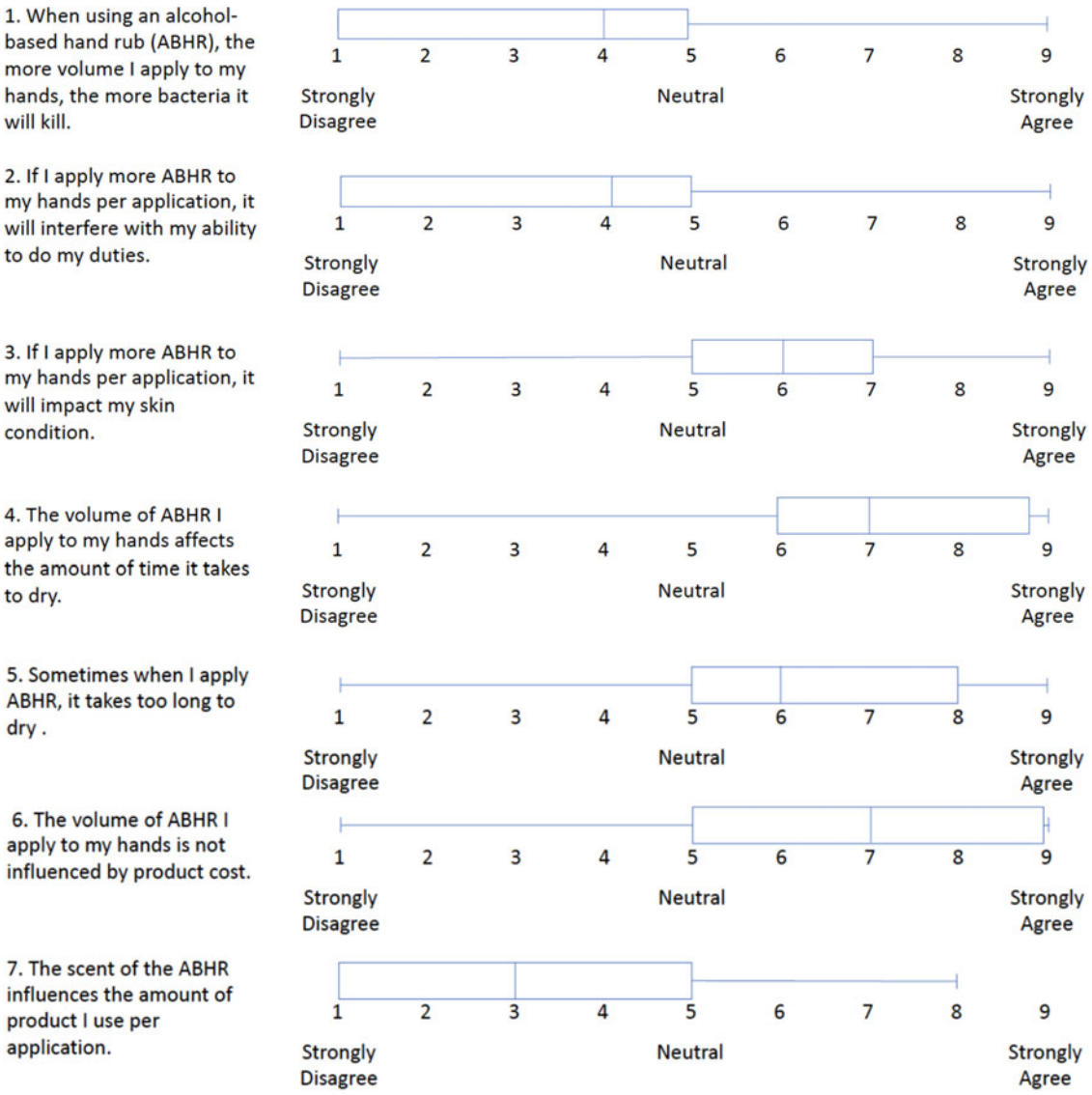


Fig. 4. Box-and-whisker plots illustrating the nurses Likert scale responses where the bar shows the range, the box shows the interquartile range, and the vertical mark shows the median.

between hand surface area and preferred average dose size in aggregate ($P = .569$) or when each hand-size group was analyzed independently ($P = .246$) (Fig. 3).

The average volume of ABHR per hand hygiene event was greater among non-ICU versus ICU staff, but the difference was not significant (1.18 vs 0.96 mL per application; $P = .251$). Most of the variation in ABHR dose volume occurred between nurse subjects, with less variation due to differences between units or within individual subject use across shifts. The variation in the doses was large (SD, 0.61 mL/dose) compared to the average dose differences among hospital units. The largest average difference of 0.73 mL per dose was between 2 non-ICU medicine units. The unit using the greatest average volume per dose specializes in the care of patients with infectious diseases. Overall, 56% of the variability in dose volume was related to nurse-to-nurse differences; 37% was related to day-to-day differences (eg, differences in the application technique employed by the same nurse on different days); and 6% was related to unit-to-unit differences. We detected no statistically significant differences, on average, among units with respect to either the number of applications ($P = .4297$) or hand size ($P = .4421$).

Survey results showed that nursing staff were generally not aware that the volume of ABHR used is correlated with the proportion of bacteria killed and were not concerned that if a greater volume of ABHR was used, it would interfere with their duties. The participants were slightly concerned that applying a greater volume of ABHR would impact the condition of their skin. The participants noted that sometimes ABHR takes too long to dry; they agreed that cost does not influence their dose; and they disagreed about whether the scent of the ABHR product used at the institution influenced the preferred volume of ABHR used (Fig. 4). Responses from the open-ended questions (data not shown) showed an understanding that the volume of ABHR used should be sufficient to cover both the front and back of the hands to the wrists and an assumption that the standard, touch-free dispensers used throughout the hospital provided an evidence-based amount of ABHR.

https://doi.org/10.1017/ice.2019.251 Published online by Cambridge University Press

Discussion

Given the belief of some nurses that the amount of ABHR routinely delivered by dispensers is excessive and takes too long to dry, there is a need to identify the amount of ABHR per application that meets US Food and Drug Administration (FDA) criteria for effectiveness and has a drying time that is acceptable to most healthcare staff. We found that the average dose of ABHR used by nurses (1.09 mL per application) was similar to the dose provided by the hospital's standard touch-free dispensers, which deliver 1.1 mL per dose. The extent to which the automated dispensers used in the hospital influenced nurses' choices on ABHR volume could not be determined by the study design utilized. Notably, a small study by Leslie et al[5] involving 19 nurses was conducted in another hospital where ABHR was routinely obtained from manual, as opposed to automated, dispensers. The investigators used the same type of bottle with an electronic cap to assess nurses' preferences for the volume of ABHR to apply to hands. On average, the volume of a liquid formulation containing 80% (v/v) ethanol applied by nurses was 0.73 mL (range, 0.27–1.61 mL), which was lower than that recommended by the manufacturer. In contrast to our study, the average volume used per application in that study varied significantly among the 5 participating wards.[5] Another recent study by Dalziel et al[6] determined that the median volume of ABHR used in a survey of Scottish hospitals was a median volume of 1.0 mL, similar to findings in the present study. Notably, the Scottish study used a more indirect method of determining the median volume of ABHR used per hand hygiene event.

Males used somewhat larger volume of ABHR per day than females, as reported in at least 1 earlier study.[15] Although this may have been related to hand size, frequency of use could not be excluded as an alternate explanation. We found that the amount of ABHR used slightly but significantly decreased as hand hygiene was performed more frequently. This finding supports the use of automated dispensers of ABHR rather than manual pumps to ensure the provision of a proper amount. Our study was not designed to explore the reasons for this. Future assessment of the drivers of ABHR dose should consider hand hygiene frequency and the inverse relationship with dose.

Another important finding of our study was that nurses with large hands did not use significantly more ABHR per application than those with small hands. This finding was in alignment with a recent study showing the volume of ABHR selected by HCPs with large hands and those with small hands, from an offering of 1, 2, or 3 mL, was similar.[12] This finding raises the question of whether or not those with large hands were able to apply ABHR to all surfaces of their hands for effective decontamination. However, whether it is necessary to cover all surfaces of the hands to adequately reduce the number of bacteria on the hands has not been established with certainty.[11,14] Likewise, the maximum safe level of pathogenic microbes on or transferred by healthcare staff hands also remains uncertain.

This study has several limitations. The study was conducted in a single large academic medical center in the United States, involved only inpatient units, and enrolled only nurses. We did not assess hand hygiene technique, the degree to which nurses covered all surfaces of their hands, or antimicrobial efficacy and the survey was not tested to determine its reliability or validity. Finally, we were not able to assess time as a variable as the electronic caps solely recorded bottle openings and only assessed hand hygiene performed using ABHR from the special bottle. Therefore, we were unable to measure the density of hand hygiene or episodes of hand hygiene in which soap and water was used, the distribution of hand hygiene episodes over the shifts, or how these variables may have affected the volume of ABHR used.

In conclusion, our findings suggest that there is substantial variability among nurses in the volume of ABHR used per application. Importantly, we found no correlation between hand surface area and preferred volume of ABHR applied. The volume of ABHR dose preferred was shown to be inversely correlated with the number of applications of ABHR per shift on most units. Further research to understand differences and drivers between wards (eg, ICUs compared with non-ICUs) and factors that influence nurses' hand hygiene behaviors and preferred volume of ABHR is needed. Based on earlier studies and our findings, the preferred ABHR dose volume may or may not be sufficient to provide appropriate reduction of bacteria on hands, depending in part on the product formulation used.[11,16] These findings should contribute to future considerations for product formulation and the design of automated dispensers of ABHR.

Acknowledgments. We thank the nurses who participated in this project and Yale New Haven Hospital nurses and nursing leadership for their support. We also thank GOJO technical personnel Dave Macinga and Rachel Leslie for their input on study design and Jackson Wegelin for engineering the bottle with counting cap.

Financial support. ABHR, electronic cap bottles and other materials necessary for the study were provided by GOJO Industries.

Conflicts of interest. J.M.B. is a consultant to Diversey, Global Life Technologies, and GOJO Industries and has received honorarium from Sodexo Healthcare. J.M.B. has also received travel support from Diversey and GOJO Industries.

References

1. Macinga DR, Shumaker DJ, Werner HP *et al.* The relative influences of product volume, delivery format and alcohol concentration on dry-time and efficacy of alcohol-based hand rubs. *BMC Infect Dis* 2014;14:511.
2. Wilkinson MAC, Ormandy K, Bradley CR, Fraise AP, Hines J. Dose considerations for alcohol-based hand rubs. *J Hosp Infect* 2017;95:175–182.
3. Suchomel M, Leslie RA, Parker AE, Macinga DR. How long is enough? Identification of product dry-time as a primary driver of alcohol-based hand rub efficacy. *Antimicrob Resist Infect Control* 2018;7:65.
4. Kohan C, Ligi C, Dumigan DG, Boyce JM. The importance of evaluating product dispensers when selecting alcohol-based handrubs. *Am J Infect Control* 2002;30:373–375.
5. Leslie RA, Donskey CJ, Zabarsky TF *et al.* Measuring alocohol-based hand rub volume used by healthcare workers in practice. *Antimicrob Resist Infect Control* 2015;7:P295.
6. Dalziel C, McIntyre J, Chand AG, McWilliam S, Ritchie L. Validation of a national hand hygiene proxy measure in NHS Scotland. *J Hosp Infect* 2018;98:375–377.
7. Stahmeyer JT, Lutze B, von LT, Chaberny IF, Krauth C. Hand hygiene in intensive care units: a matter of time? *J Hosp Infect* 2017;95:338–343.
8. Macdonald DJ, Mckillop EC, Trotter S, Gray AJ. One plunge or two? Hand disinfection with alcohol gel. *Int J Qual Health Care* 2006;18:120–122.
9. Goroncy-Bermes P, Koburger T, Meyer B. Impact of the amount of hand rub applied in hygienic hand disinfection on the reduction of microbial counts on hands. *J Hosp Infect* 2010;74:212–218.
10. Kampf G, Ruselack S, Eggerstedt S, Nowak N, Bashir M. Less and less—influence of volume on hand coverage and bactericidal efficacy in hand disinfection. *BMC Infect Dis* 2013;13:472.
11. Bellissimo-Rodrigues F, Soule H, Gayet-Ageron A, Martin Y, Pittet D. Should alcohol-based handrub use be customized to healthcare workers' hand size? *Infect Control Hosp Epidemiol* 2016;37:219–221.

https://doi.org/10.1017/ice.2019.251 Published online by Cambridge University Press

12. Zingg W, Haidegger T, Pittet D. Hand coverage by alcohol-based handrub varies: volume and hand size matter. *Am J Infect Control* 2016;44:1689–1691.
13. Lee JY, Choi JW, Kim H. Determination of hand surface area by sex and body shape using alginate. *J Physiol Anthropol* 2007;26:475–483.
14. Reilly JS, Price L, Lang S *et al.* A pragmatic randomized controlled trial of 6-step vs 3-step hand hygiene technique in acute hospital care in the United Kingdom. *Infect Control Hosp Epidemiol* 2016;37:661–666.
15. Pittet D, Allegranzi B, Sax H *et al.* Double-blind, randomized, crossover trial of 3 hand rub formulations: fast-track evaluation of tolerability and acceptability. *Infect Control Hosp Epidemiol* 2007;28:1344–1351.
16. Macinga DR, Edmonds SL, Campbell E, Shumaker DJ, Arbogast JW. Efficacy of novel alcohol-based hand rub products at typical in-use volumes. *Infect Control Hosp Epidemiol* 2013;34:299–301.

https://doi.org/10.1017/ice.2019.251 Published online by Cambridge University Press