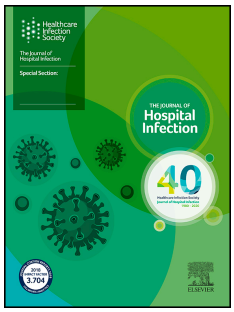
Low efficacy of three non-alcohol-based hand disinfectants utilizing silver polymer, lactic acid and benzalkonium chloride on inactivation of bacteria on the fingertips of healthcare workers

Lehtinen, Jaana-Marija

W.B. Saunders Ltd
2022-07

Lehtinen, J-M, Kanerva, M, Tarkka, E, Ollgren, J & Anttila, V-J 2022, 'Low efficacy of three non-alcohol-based hand disinfectants utilizing silver polymer, lactic acid and benzalkonium chloride on inactivation of bacteria on the fingertips of healthcare workers', Journal of Hospital Infection, vol. 125, pp. 55-59. https://doi.org/10.1016/j.jhin.2022.03.012

http://hdl.handle.net/10138/569824
10.1016/j.jhin.2022.03.012



Low efficacy of three non-alcohol-based hand disinfectants utilizing silver polymer, lactic acid and benzalkonium chloride on inactivation of bacteria in healthcare workers' fingertips

Janna-Marija Lehtinen, Mari Kanerva, Eveliina Tarkka, Jukka Ollgren, Veli-Jukka Anttila

PII: S0195-6701(22)00100-1

DOI: https://doi.org/10.1016/j.jhin.2022.03.012

Reference: YJHIN 6635

To appear in: *Journal of Hospital Infection*

Received Date: 5 January 2022

Revised Date: 26 March 2022

Accepted Date: 28 March 2022

Please cite this article as: Lehtinen J-M, Kanerva M, Tarkka E, Ollgren J, Anttila V-J, Low efficacy of three non-alcohol-based hand disinfectants utilizing silver polymer, lactic acid and benzalkonium chloride on inactivation of bacteria in healthcare workers' fingertips, *Journal of Hospital Infection*, https://doi.org/10.1016/j.jhin.2022.03.012.

Low efficacy of three non-alcohol-based hand disinfectants utilizing silver polymer, lactic acid and benzalkonium chloride on inactivation of bacteria in healthcare workers' fingertips

Janna-Marija Lehtinen,[1] Mari Kanerva,[1] EveliinaTarkka,[2] Jukka Ollgren,[3] Veli-Jukka Anttila[1]

[1]Inflammation Centre, Division of Infectious diseases, University of Helsinki and Helsinki University Hospital, Helsinki, Finland

[2]HUSLAB, University of Helsinki and Helsinki University Hospital, Helsinki, Finland

[3] Department of Health Security, Finnish Institute for Health and Welfare, Helsinki, Finland

Corresponding author:

Jaana-Marija Lehtinen,

Division of Infectious Diseases,

Helsinki University Hospital,

PL 372, 00029 HUS, Finland

jaana-marija.lehtinen@thl.fi

Running Title: Low efficacy of non-alcoholic hand rubs

Summary (221words)

Background: Recently, new non-alcohol-based hand disinfection formulae have come to the market. Although they have passed the EN1500 test, data on their clinical efficacy compared with alcohol-based hand rubs is scarce, covering mainly benzalconium chloride (BAC).

Aim: To test the efficacy of one silver polymer, one lactic acid and one BAC-based hand disinfectant foam, and one alcohol-based hand rub gel, in reducing bacterial counts on the health care workers' fingertips working at hospital wards.

Methods: Each of the 84 testers tested one of the four products during their morning shift at a hospital ward using the 'fingertips on Petri dish' method before and after rubbing hands with the product. After incubation, two independent readers assessed bacterial counts on the culture plates.

Findings: The alcohol-based hand rub efficiently reduced bacteria from the testers' fingertips in the test situation, whereas two of the tested products (lactic acid and BAC) did not have any detectable efficacy on bacteria present on the testers' fingertips at a patient ward. The silver polymer-based formula had some effect, but requires further study.

Conclusion: Non-alcohol-based hand rubs require careful consideration and further study before they can be accepted for clinical use.

Keywords: hand disinfectant, non-alcohol-based rub, ethanol-based rub, BAC-based rub, lactic-acid-based rub, silver-polymer-based rub

Introduction

Alcohol-based hand rub formulation is commonly used in health care organizations worldwide. Since the European commission forbade the use of PHMB (polyhexamethylene biguanide, polyhexamethylene biguanide hydrochloride) as a biocidal product in human hygiene in 2016, there were no alcohol-free hand rub formulations available in Finland until 2018-2019 [1, 2]. After that, three alcohol-free hand rub formulations entered the market, silver polymer, lactic acid and benzalkonium chloride (BAC)-containing products [3-5]. All three had passed the standard test EN 1500. Chlorhexidine-based hand rubs are not available in Finland [6, 7,].

In environments where for example alcoholic abusers and drug addicts are treated, alcohol-based hand rub formulations cannot be displayed [8]. In those places, the alternative for using alcohol-based hand rub formulation has been washing hands with water and soap or using alcohol-based hand rub from small personal dispensers. Washing hands with soap and water regularly can affect skin dryness and carrying personal hand rub dispensers is not always practical [9-10]. Moreover, alcohol-based hand rubs can cause dryness and a burning sensation, or irritant contact dermatitis, especially if used repeatedly and after excess scrubbing with water and detergents [11, 12, 13]. Irritated skin can then in turn reduce compliance with hand hygiene. [12] Therefore, for several reasons there is a demand for alcohol-free hand rub formulations.

In all the new non-alcoholic hand rubs, the formulation was foam and all contain skin protective ingredients. Even though the need for these alcohol-free formulations was far from universal, several long-term care and rehabilitation providers were interested in these

and asked for an expert opinion from our infection control team at Helsinki University Hospital.

Few studies or data on these non-alcohol-based products were found in the literature [7,14-16]. In addition, they mainly looked at the long-term effects of the BAC. [15-16] We therefore decided to study the usability and efficacy of these products in a clinical setting.

Methods

We tested three non-alcohol hand disinfectants, Bea Pro (active ingredient Nolla^{TM}-silver polymer, CAS 7783-90-6) by Berner Oy, Finland, Sure Instant Hand Sanitazer (active ingredient lactic acid 1.8 w%, CAS 50-21-5) by Diversey Europe Operations B.V. (the only one of these approved in the Biocide Registry in Finland) and TecCare Protect (active ingredient benzalkonium chloride, BAC, 0.1%, CAS 68424-85-1) by Talley Environmental Care Ltd, Hants, UK, and one alcohol-based hand disinfectant LV (active ingredient ethanol 74 w%, CAS 64-17-5) by Berner Oy, Finland, during three days at eight wards in Helsinki University Central Hospital [3-5, 17]. We invited altogether 96 voluntary health care workers including nurses, doctors, and cleaners for a five-minute break to individually test one of the products during their normal working day. They were asked not to do the routine hand disinfection when interrupting their working for the test. Workers who had long or artificial nails or nail polish were excluded. We did not gather any identifying information on participants.

Before the test, the test person was asked to place his or her right-hand fingertips on a blood agar plate, with first the four fingertips and then the thumb pressed firmly but lightly for a couple of seconds under the supervision of an infection control nurse. Then they were asked to take a defined dose of one of the test products on their palm. The dosage was as suggested by the manufacturers: two doses of silver polymer-based and alcohol-based

disinfectants, one dose of BAC-based and three doses of lactic acid-based disinfectant. The volumes of each product were measured with a syringe. The foamy products were first allowed to turn back into liquid phase in a small cup. When dispensed according to the manufacturers' recommendations, two full doses of alcohol-based product contained 3.1 mL (range 2.8-3.2 mL). Two doses of the silver polymer-based product contained 1.5 mL, three doses of the lactic acid-based product contained 2.3 mL and one dose of the BAC-based product contained 0.7 ml.

While rubbing, participants were supervised by the infection control nurse who stood in front of the person modelling the hand rubbing movements after applying the product in a cupped hand: 1) first fingertips, 2) palms against each other with the fingers intertwined 3) the back of the hands 4) the thumbs 5) fingers crooked against each other. Wrists or arms were not rubbed. The participants were instructed to rub their hands until hands were so dry that they could wear protective gloves. An assisting researcher timed all the rubbings with a stopwatch. Immediately after rubbing, the persons were asked to place his or her fingers of the same hand on another culture plate. Individuals who did not follow the instructions were excluded from the analysis.

Twenty-one workers tested each product successfully. All products were in 500 mL pump dispensers. During each of the three testing days, we tested all four products and we opened new bottles of the products for each testing day. During the last testing day, two rubbings and finger sampling for each product were recorded on video. Each recorded test person approved the recording.

After two days incubation the bacterial inocula of each five fingers were evaluated by two independent readers, VJA and ET. The index count for a finger was defined as 0 if there was

one, or no, bacterial colonies; 1 if there were two to nine bacterial colonies; 2 if there were ten or more discrete bacterial colonies; and 3 if there was a semi-confluent or confluent growth (Supplementary Figure 1). The index counts of all five fingers were added together, so that the maximum summary index count of a hand was 15. The final summary index count for a hand was expressed as a mean of the two readers' evaluations.

Stata 16.1 statistics were used for the data analysis. Pearson Chi2, Fisher`s exact, Kruskal Wallis tests were used. Bootstrap has been used to calculate confidence intervals; the number of iterations was 1000.

Results

Altogether, 84 eligible healthcare workers were included in the study, 21 for each disinfectant formulation.

The correlation of the counts read by the two readers (VJA and ET) was high, Spearman correlation coefficients for the readers' counts in the Petri dishes before and after hand disinfection were 0.970 ($p < 0.001$) and 0.978 ($p < 0.001$).

The means of the final summary index counts of the testers' hands before hand disinfection did not significantly differ between the product groups. It varied from 7.8 (95% CI 6.0-9.6) for alcohol-based to 5.8 (95% CI 4.0-7.8) for BAC-based hand disinfectant group (Figure 1a). However, there were differences in the medians of final summary index counts after using the different disinfectant products (Figure 1b). The lowest number of bacteria were seen in the alcohol-based disinfectant group (mean summary index count 1.8; 95% CI 0.4-3.1) and the highest number in the BAC-based hand disinfectant group (mean summary index count 8.0; 95% CI 5.5-10.7)

Statistically significant reductions were observed between the before and after mean summary index counts and these reductions also differed between groups (Table 1). The largest decrease between before and after counts was observed with alcohol-based hand rub group. Some reduction also occurred in silver polymer-based testers' fingers. However, there was no difference in the bacterial counts in fingers after using the lactic acid-based product. In the BAC-based group the mean summary index counts even increased.

The drying times varied among the same products: in alcohol-based group, median time was 1.5 minutes (range 0.8-2.3 minutes), in silver polymer-based group 2.2 minutes (range 1.23-4.7), in lactic acid-based group 2.8 minutes (range 1.85-7.6) and in BAC-based group 1.7 minutes (range 1.0-3.1). No significant correlations were seen between the drying times and the efficacy of the hand disinfectant products (Figure 2).

Discussion

Testing of three non-alcoholic hand rub formulations available on the Finnish market showed that two of them, BAC and lactic acid-based products were ineffective in reducing bacterial counts on the testers' fingertips. The third one containing silver polymer probably had some effect but less than alcohol-based hand rub formulation.

All the products, we tested had passed the test EN1500 before reaching the market [3-5, 17]. We did not repeat that test but aimed to re-examine their efficacy in a real-life situation focusing on fingertips, and using our "fingertips on Petri dish" method. A reduction in bacterial counts on the fingertips may be the most important impact of hand rub formulations, because critical items such as iv cannulas are touched by fingertips. We did not use test bacteria, and we did not identify bacteria isolated from finger tips. Thus, it cannot be concluded categorically that the test products were effective in reducing or

eliminating more pathogenic bacteria. We note that EN tests only measure transient flora, which is more likely to comprise bacteria of medical importance.

The long drying times over two minutes of the non-alcoholic hand rub formulations presumably reflected slower evaporation. This is a practical concern because time is lost before clinical activities can be undertaken. Also, drying and rubbing times may be associated with skin damage and irritation, and might in addition be more likely to remove the protective normal skin flora thus exposing hands to more virulent bacteria.

The fact that the BAC-based product was largely ineffective contrasts with previous studies that showed that BAC has good or even superior efficacy to alcohol when using test bacteria e.g., *Serratia* spp.*, Staphylococcus aureus* or *Escherichia coli* [15,18-19]. BAC was also more effective than alcohol hand rub in a study using a similar fingertip test method to ours, and in ward conditions without added test bacteria [16]. Our different result could be due to the method, as we did not use test bacteria but instead measured reduction in bacteria encountered in the fingertips during normal patient work. Our results might also apply only to the specific commercial products tested. Chojnacki et al. tested various hand rub products against *S. aureu*s and *E. coli* and found variation in efficacy according to viscosity of alcohol-based rubs [19]. We also note that the recommended volume of the BAC-based product in our study was smaller than that recommended by comparators, which may also explain a difference in efficacy.

A strength of our study is that testing was carefully planned. Product application was directly observed by an infection control nurse, and some performances were video recorded for internal quality control. A new three-step technique for hand disinfection has

recently been proposed, where disinfectant is first rubbed on all surfaces of hands, then the fingertips and finally the thumbs [20]. However, we used the five-step method in use in our institution at the time of the study. Wrists and elbows were not rubbed, to avoid the risk of contaminating the finger tips during the final stages of rubbing.

Other strengths were that the study was carried out over during three days, on two to four wards daily, to control differences between wards and to avoid fatigue for the supervising infection control nurse. Care was taken to avoid the contamination of the bottles. Weaknesses of our study include the lack of use of inhibitors in the culture media, although given that bacteria were able to be isolated after use of the test products suggests that this did not influence the results. The study was anonymized, meaning that any effect of age or gender on the results cannot be ascertained. Each tester tested only one hand, and so the influence of using the dominant or non-dominant hand cannot be assessed. Although the current state of the skin or participants was assessed as healthy by the infection control nurse, details of any previous skin problems were not recorded.

Conclusion

In our study on hospital wards, alcohol-based hand rub showed the most reliable efficacy. Further, larger, studies are required to ascertain whether any of the non-alcohol-based products are suitable for clinical use.

Acknowledgements

We thank Ms Nina Pekonen and Ms Laura Kanerva for technical assistance.

Declarations of interest

None

Funding

None declared

References

[1] Official Journal of the European Union 27.1.2016. Commission Implementing Decision (EU) 2016/109. http://data.europa.eu/eli/dec_impl/2016/109 [accessed 14 October 2021].

[2] European Chemical Agency. Substance infocard: PHMB; polyhexamethylene biganude hydrochloride. https://echa.europa.eu/fi/substance-information/-/substanceinfo/100.115.789 [accessed 14 October 2021].

[3] Bea Pro hand disinfectant, product card and user safety information. https://www.berner.fi/pro/tuote/bea-pro-alkoholiton-kasihuuhdevaahto/ [accessed 14 October 2021].

[4] SURE Instant Hand Sanitizer, product card. http://diverseysolutions.com/fi/Category/152/Product/45993 [accessed 14 October 2021].

[5] TECcare Technologies Fact Sheet. https://www.teccare.com/medias/documents/TECcare-PROTECT-Foam-Hand-Sanitiser---Fact-Sheet-(April-17)-e-3-1583838263.pdf [accessed 14 October 2021].

[6] Nhung DT, Freydiere AM, Constant H, Falson F, Pirot F. Sustained antibacterial effect of a hand rub gel incorporating chlorhexdine-loaded nanocapsules (Nanochlorex). Int J Pharm. 2007; 334: 166–72. https://doi.org/10.1016/j.ijpharm.2006.10.017

[7] Review of preparations used for hand hygiene and WHO-recommended hand rub formulations. WHO Guidelines on hand hygiene in health care 2009; pages 3048. https://apps.who.int/iris/bitstream/handle/10665/44102/9789241597906_eng.pdf;jsessionid=2EC2AECA63F7BCC495E9B96793523B54?sequence=1 [accessed 14 October 2021].

[8] Gormley NJ, Bornstein AC, Rasimas JJ, Pao M, Wratney AT, Sun J *et al.* The rising incidence of intentional ingestion of ethanol-containing hand sanitizers. Crit Care Med 2012; 40: 290-4. https://dx.doi.org/10.1097%2FCCM.0b013e31822f09c0

[9] Skin reactions related to hand hygiene. WHO Guidelines on hand hygiene in health care 2009: 61-3. https://apps.who.int/iris/bitstream/handle/10665/44102/9789241597906_eng.pdf;jsessionid=2EC2AECA63F7BCC495E9B96793523B54?sequence=1 [accessed 16 October 2021].

[10] Winnefeld M, Richard MA, Drancourt M, Grob JJ. Skin tolerance and effectiveness of two hand decontamination procedures in everyday hospital use. Br J Dermatol 2000; 143: 546-50. https://doi.org/10.1111/j.1365-2133.2000.03708.x

[11] Centers for Disease Control and Prevention. Guideline for Hand Hygiene in Health-Care Settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. MMWR 2002;51(No. RR16):[18-20]. https://www.cdc.gov/mmwr/PDF/rr/rr5116.pdf [accessed February 2, 2022]

[12] Kampf G, Kramer A. Epidemiologic Background of Hand Hygiene and Evaluation of the Most Important Agents for Scrubs and Rubs. Clinical Microbiological Reviews 2004; 4: 863-93. https://doi.org/10.1128/CMR.17.4.863-893.2004

(13) Plum F, Yüksel YT, Agner T, Nørresle LB. Skin barrier function after repeated short-term application of alcohol-based hand rub following intervention with water immersion or occlusion. Contact Dermatitis 2020; 3: 215-9. https://doi.org/10.1111/cod.13587

[14] Espadale E, Pinchbeck G, Williams NJ, Timofte D, McIntyre KM, Schmidt VM. Are the Hands of Veterinary Staff a Reservoir for Antimicrobial-Resistant Bacteria? A Randomized

Study to Evaluate Two Hand Hygiene Rubs in a Veterinary Hospital. Microb Drug Resist 2018;24(10):1607-1616. https:// doi:10.1089/mdr.2018.0183

[15] Bondurant SW, Duley CM, Harbell JW. Demonstrating the persistent antibacterial efficacy of a hand sanitizer containing benzalkonium chloride on human skin at 1, 2, and 4 hours after application. Am J Infect Control 2019; 47: 928−932. https://doi.org/10.1016/j.ajic.2019.01.004

[16] Bondurant S, McKinney T, Bondurant L, Fitzpatrick L. Evaluation of benzalkoium chloride hand sanitizer in reducing transient *Staphylococcus aureus* bacterial skin contamination in health care workers. Am J Infect Control 2020; 48: 522-526. https://doi.org/10.1016/j.ajic.2019.08.030

[17] LV alcohol-based hand disinfectant, product information. https://www.bernerbrandbank.fi/l/rh95xpmGhrmw [accessed 16 October 2021].

[18] Dyers DL, Gerenraich K, Wadhams PS. Testing a New Alcohol-Free Hand Sanitizer to Combat Infection. AORN journal 1998, 68: 239-250. https://doi.org/10.1016/s0001-2092(06)62517-9

[19] Chojnacki M, Dobrotka C, Osborn R, Johnson W, Young M, Meyer B *et al.* Evaluating the antimicrobial properties of commercial hand sanitizers. mSphere 2021; 6: e00062-21. https://doi.org/10.1128/mSphere.00062-21.

[20] Tschudin-Sutter S, Rotter ML, Frei R, Nogarth T, Häysermann P, Stranden A *et al.* Simplifying the WHO `how to hand rub` technique: three steps are as effective as six – results from an experimental randomized crossover trial. Clin Microbiol infect 2017; 23: 409.e1-e4. https://doi.org/10.1016/j.cmi.2016.12.030

FIGURE CAPTIONS

Figures 1a-b

Boxplots of the final summary index bacterial counts before (a) and after (b) use of hand disinfection with each hand disinfectant product

Figure 2

Correlation between the drying time of a hand disinfectant and its efficacy (i.e. reduction in the mean index bacterial counts between the before and after use measurements) in each hand disinfectant product.

Supplementary Figures 1 a-d

Examples of determination of an index count of bacterial colonies on culture plates

Figure 1a: Index count zero.

Figure 1b: Index count one

Figure 1c: Index count two

Figure 1d: Index count three

Table 1

Reduction of the final summary index bacterial counts of testers' fingers in each group between before and after using the hand disinfectant.

Each finger`s index count was defined with numerals 0-3 depending on the quantity of bacterial colonies, the maximum possible index count of a hand being 15.

	Mean reduction	95% CI		Median reduction	Min reduction	Max reduction
Ethanol-based	6.02	4.14	7.91	5	0	15
Silver polymer-based	3.64	2.18	5.11	4	-3	8.5
Lactic acid-based	0.17	-2.77	3.10	0	-12.5	10
BAC-based	-2.14	-4.08	-0.20	-1.5	-8.5	6.5

Figure 1a.

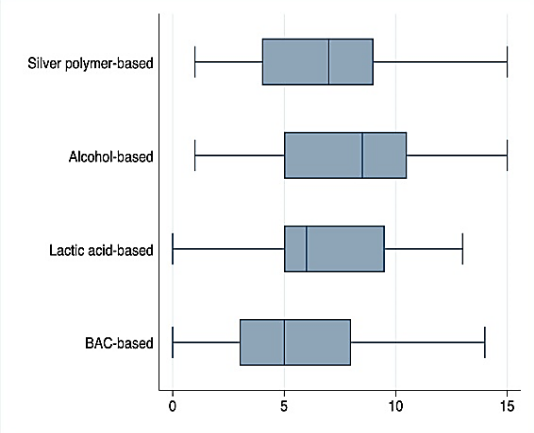


Figure 1b.

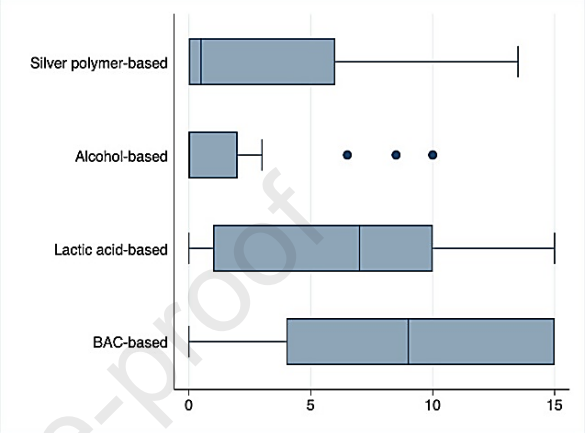


Figure 2