

Short-term effects of alcohol-based disinfectant and detergent on skin irritation

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The most important risk factor for occupational contact dermatitis in hospital personnel is the exposure to irritants such as water, detergents and alcohol-based solutions. This study was undertaken to evaluate the short-term effects of repeated exposure to an alcohol-based disinfectant, to a detergent and to an alcohol-based disinfectant/detergent alternately. The hardening effect in preirritated skin after a 4-week interval was also evaluated. Detergent, disinfectant and disinfectant/detergent alternately were applied daily every 15 min for 6 h for 2 days to the flexor upper arms and forearms of 15 volunteers. A control area was included. After 4 weeks, a sodium lauryl sulfate patch was applied to each area. Irritant reactions were quantified by visual score, transepidermal water loss (TEWL) and skin colour at baseline, D3, D8, D35 and D37. As evaluated by clinical assessment, detergent caused more redness of the skin than both disinfectant applied alone and disinfectant/detergent alternately at D3 and D8, $P < 0.001$ and $P < 0.001$, respectively. An increased irritant response for detergent as compared to disinfectant alone and disinfectant/detergent was confirmed by TEWL and colour evaluations, $P = 0.001$ and $P = 0.001$ and $P = 0.006$ and $P = 0.009$, respectively. No hardening effect in preirritated skin was found after a 4-week interval. In conclusion, hand disinfection with alcohol-based disinfectant or alternate use of disinfectant/detergent causes less skin irritation than hand disinfection with a detergent. This study evaluated the short-term effects of disinfectant and detergent exposure only, and more long-term studies are necessary before recommendations can be made.

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The potential of detergents to cause skin irritation varies considerably (1). Previously, the antimicrobial effects of hand disinfectants, as well as compliance aspects of detergents versus disinfectants, have been evaluated (2, 3). With respect to reduction in microorganisms, alcohol-based solutions are now favoured over conventional handwashing with soap. Improvement in compliance with hand disinfection with disinfectant compared to detergent has been demonstrated. Evaluation of skin tolerance has been made (4–7). Focus in this article is on skin tolerance.

Frequent and repeated use of hand-hygiene products, particularly soaps and other detergents, are a primary cause of chronic irritant contact dermatitis (ICD) among health care workers (8). Minimizing hand disinfectant-related ICD requires knowledge about the precise irritant effects of soaps and disinfectants used (8). In some studies,

alcohol-based disinfectants are reported to be less irritant than the standard hygienic handwashing procedure during regular work in clinical wards and intensive care units (4–6, 9, 10). However, other studies have proved disinfectants to be one of the main risk factors for development of hand eczema (11, 12). Also, combined exposures to detergents and disinfectants have been studied (13, 14) and an experimental study indicates that short-term exposure to sodium lauryl sulfate (SLS) and *n*-propanol does not lead to enhanced skin irritation as compared to single application of these irritants (13, 14). The hypothesis that repeated short-term exposure to a single irritant (detergent) decreases the inflammatory reaction compared to repeated short-term exposure to 2 chemically different agents was tested, as well as whether a hardening effect on the skin could be demonstrated after 4 weeks.

Materials and Methods

Subjects

15 healthy volunteers [7 women and 8 men, mean age 25.2 years (range 23–27)] without any skin diseases or atopic dermatitis were included in the study after approval by the local Ethics Committee of Copenhagen. Informed consent was obtained from each participant. Subjects were allowed to bathe as usual but were instructed to avoid application of detergents, moisturizers or emollients on the upper arms and forearms during the investigation.

Materials

Detergent. Liquid soaps including the following ingredients: aqua, sodium laureth sulfate, sodium laureth-8 carboxylate + laureth-7, glycereth-2-cocoate, glycerin, PEG-4 rapeseed amide, lactic acid.

Alcohol disinfection. Alcohol hand disinfection containing 1.3% glycerol, 5% v/v isopropyl alcohol and 78% v/v ethanol.

Procedure

The washing procedure took place at the Department of Dermatology under supervision.

The application areas were clinically normal skin of the flexor upper arms and forearms. Each of the 4 test areas was 5 × 10 cm and placed on the flexor upper arms and forearms, respectively. The participants were instructed by the investigator to wash and disinfect test areas. Test areas were to be washed or disinfected every 15 min for 6 h for 2 days. The placement of the 4 test fields on the arms was randomized.

1 test area was treated with repeated applications of undiluted detergent, rubbed into the skin for 20 s using the opposite hand and afterwards rinsed off with lukewarm tapwater (30°C–36°C) for another 20 s. Afterwards, it was dried with a towel. On the 2nd test area, repeated application with 3 ml of alcohol-based hand disinfectant was rubbed into the skin for 20 s and afterwards air dried. On the 3rd area, repeated application of alcohol-based disinfectant/detergent alternately, with a 15-min interval between each application, was performed according to the procedure described above. The 4th test area was included as a control site.

After an interval of 4 weeks, patch tests with 1% aqueous SLS (>99% purity, Sigma Chemical Co, St. Louis, MO, USA) was applied for 24 h in all 4 test areas using 12-mm Finn Chambers[®] (Epitest, Tuusula, Finland) to evaluate a possible

hardening effect. No emollients or detergents were applied on the arms during the entire experiment.

Evaluation methods

The study was carried out from February to April 2004. All visual scorings and bioengineering measurements were performed to compare the intensity of reactions before starting treatments on day 1 (D1), D3, D8, D35 and D37 by the same observer under controlled environmental conditions. Before measurement of transepidermal water loss (TEWL) the test persons rested for 30 min. All measurements were carried out at 19°C–25°C room temperature with relative humidity between 21% and 39%.

Clinical score for test sites graded for erythema, scaling and fissuring was recorded according to Frosch and Kligman (15). The maximum possible score for this scoring system is 10.

Transepidermal water loss (TEWL, g/m² h) was measured by the Dermalab[®] system equipped with a TEWL probe by Cortex Technology Aps, Hadsund Denmark, according to the guidelines of the ESCD on measurement of TEWL (16). Instrumental colour measurements were taken with a Minolta Chromameter (CR-300, Minolta, Osaka, Japan) according to published recommendations (17). The colour coordinates were expressed in the L*, a*, b* 3-dimensional colourimetric system. The a* value is the component of separation between red (positive value) and green (negative value) and is a sensitive measure for quantifying erythema.

Statistical methods

Statistical analysis was conducted using SPSS/PC+ (version 11.0, SPSS, Chicago, IL, USA). For comparison between test substances, Friedman's test was chosen followed by the Wilcoxon signed ranks test used for continuous data (TEWL and colourimetric measurements).

Clinical data (erythema score) were analyzed using Fisher's exact test, comparing the control, disinfectant, detergent and disinfectant/detergent test sites. The chosen level of significance was $P < 0.05$.

Results

Results of clinical scorings at D3 and D8 (Figs 1 and 2)

No scaling or fissuring was found at any of the test sites. Detergent caused more redness of the skin than both disinfectant applied alone and

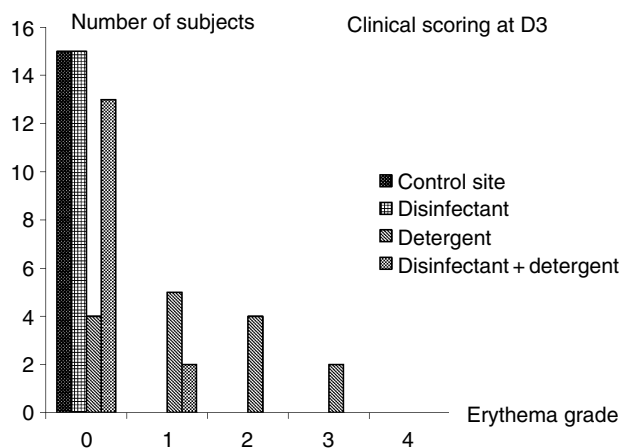


Fig. 1. Clinical reactions at control, disinfectant, detergent and disinfectant/detergent test sites at D3. The erythema grade is indicated on the x-axis and the number of subjects is given on the y-axis. Detergent caused more redness of the skin than both disinfectant applied alone and disinfectant/detergent alternately at D3, $P < 0.001$.

disinfectant/detergent alternately at D3 and D8, $P < 0.001$ and $P < 0.001$, respectively.

Results of TEWL measurements at D1, D3 and D8 (Fig. 3)

Repeated exposure to detergent as compared to disinfectant was found to differ statistically significantly at D3, with higher TEWL values from the detergent indicating more barrier damage for detergent compared to disinfectant, $P = 0.001$. TEWL values for detergent compared to disinfectant/detergent, alternately, were statistically significantly higher at D3, indicating more barrier disruption from detergent than from disinfectant/detergent alter-

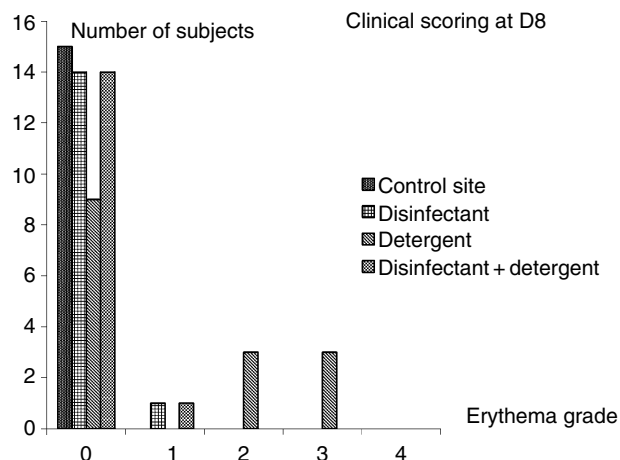


Fig. 2. Clinical reactions at control, disinfectant, detergent and disinfectant/detergent test sites at D8. The erythema grade is indicated on the x-axis and the number of subjects is given on the y-axis. Detergent caused more redness of the skin than both disinfectant applied alone and disinfectant/detergent alternately at D8, $P < 0.001$.

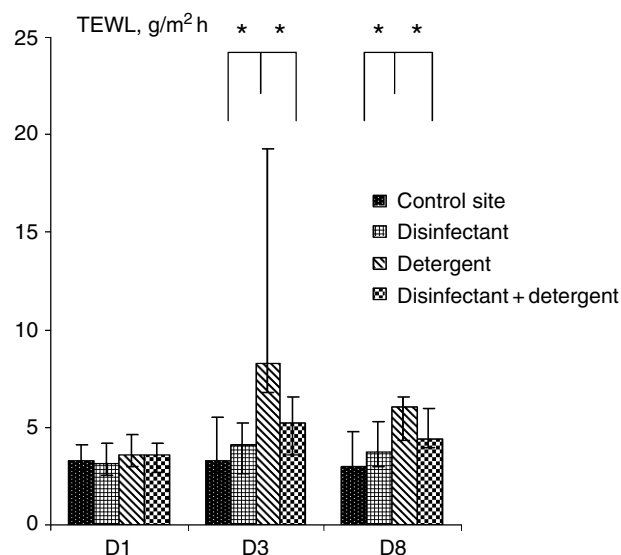


Fig. 3. Comparison of evaporimetric responses between control site, disinfectant, detergent and disinfectant/detergent on D1, D3 and D8 (median values and 25/75 percentiles), $*P < 0.05$.

nately, $P = 0.001$. Disinfectant caused statistically significantly lower TEWL values as compared to disinfectant/detergent alternately at D3, $P = 0.001$. At D8, a statistically significant difference between detergent versus disinfectant and detergent versus disinfectant/detergent was found, $P = 0.035$ and $P = 0.001$, respectively.

Results of colourimetry at D1, D3 and D8 (Fig. 4)

Repeated exposure to detergent as compared to disinfectant was found to differ statistically significantly at D3, with more erythema from the detergent indicating more inflammation from detergent compared to disinfectant, $P = 0.006$. Erythema from detergent compared to disinfectant/detergent alternately was statistically significantly higher at D3, indicating more erythema from detergent than from disinfectant/detergent alternately, $P = 0.009$. Disinfectant caused no statistically significantly less redness as compared to disinfectant/detergent alternately at D3, $P = 0.233$. At D8, a statistically significant difference between detergent versus disinfectant and detergent versus disinfectant/detergent was found, $P = 0.018$ and $P = 0.005$, respectively.

Hardening effect after patch test with SLS

Results of TEWL measurements at D37 are shown in Fig. 5. No differences between the test sites were found. Also for Δ TEWL, no significant differences were found.

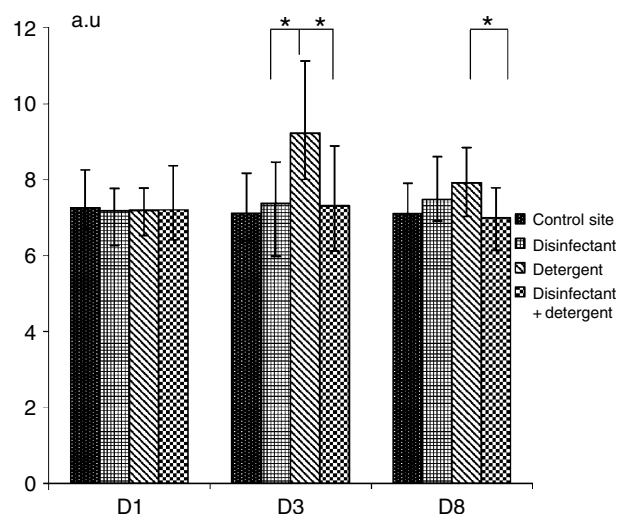


Fig. 4. Comparison of colourimetric responses between control site, disinfectant and disinfectant/detergent on D1, D3 and D8 (median values and 25/75 percentiles), * $P < 0.05$.

At D35, no statistically significant difference was found between test sites, $P = 0.113$.

Results of colourimetry at D37 are shown in Fig. 6. No differences between the test sites were found. Also for Δa^* -values, no significant differences were found.

At D35, no statistically significant difference was found between test sites, $P = 0.252$.

Discussion

In this short-term study, detergents were shown to affect the skin to a higher degree than alcohol-

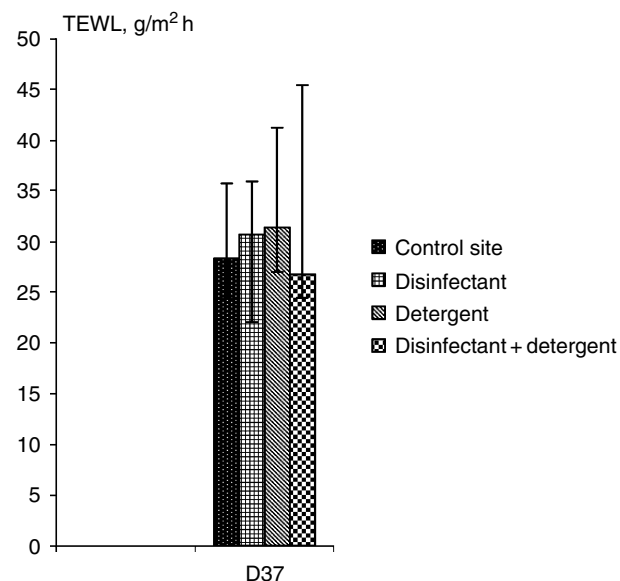


Fig. 5. Transepidermal water loss (TEWL) at D37. No statistically significant difference between test sites, $P = 0.207$, indicating no hardening effect.

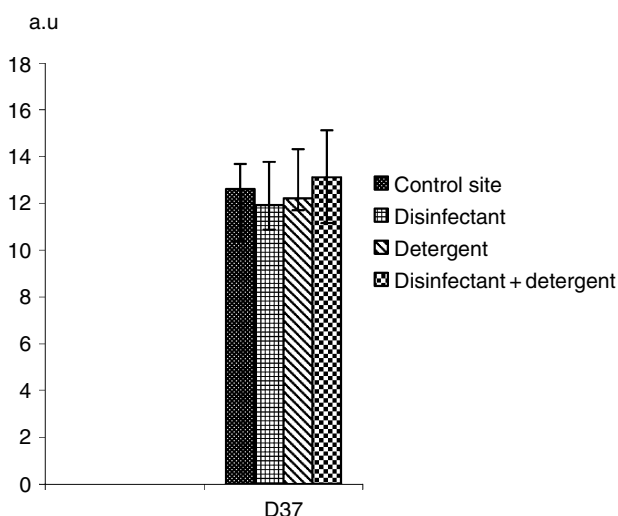


Fig. 6. Colourimetry at D37. No statistically significant difference between test sites, $P = 0.165$, indicating no hardening effect.

based disinfectant/detergent and alcohol-based disinfectant applied separately, when evaluated by clinical scoring, measurement of skin barrier function impairment (TEWL) and skin redness (colourimetry) (Figs 1 and 2). Combination of disinfectant/detergent causes less skin irritation than detergent separately, probably due to a diminished total amount of detergent exposure. The hypothesis that repeated short-term exposure to a single irritant (detergent) decreases the inflammatory reaction compared to repeated short-term exposure to 2 chemically different agents was tested. The combined exposure caused an irritant effect which was increased as compared to disinfectant alone and decreased as compared to detergent alone. From this experimental design, it is difficult to conclude as to additive or synergistic effects. For this to be clarified, another design would have to be established whereby the same total dose of each irritant was applied in the combined area. However, the aim here was to provide a realistic exposure assessment. In a comparable study, however, a combination of SLS and toluene (14) was reported to lead to an enhanced response compared to single application of the 2 irritants.

Alcohol-based solutions have been reported to cause less skin irritation than detergents or soaps (7), when evaluated by measurement of skin hydration and visual assessments. The present study confirmed this result, including measurements of TEWL, which is the best method to evaluate skin damage due to chronic ICD. Winnefield et al. (5) also found that alcohol-based hand disinfectants were less irritating than soaps

when evaluated by clinical assessment and TEWL. Their study was different from the current study, because it was not a paired design. Similar results were obtained from a study by Pietsch (4) when evaluated by D-squames, skin roughness and TEWL.

With respect to hardening, a study by Hindsen and Bruze (18) showed a decreased skin reactivity (hyporeactivity) 4 weeks after application of nickel to a previous dermatitis test site with SLS (18). Effects of repeated application of detergent has also been studied. Freeman and Maibach (19) showed an increased skin reactivity to SLS when applied after 2 weeks to a test site with previous ICD from SLS. Long-term effects of cumulative ICD on skin barrier function have been evaluated; experimental ICD was induced and skin reactivity to SLS evaluated. 6 and 9 weeks after irritation, a hyporeactivity of preirritated test site was noted (20), indicating that postcumulative irritation hyporeactivity starts at 6 weeks and lasts for a minimum of 9 weeks. In our study, we were not able to confirm a hardening effect following either detergent or disinfectant exposure 4 weeks earlier. This can be explained either by the short exposure time (2 days) or the weak irritant reaction that was elicited (Figs 1 and 2). The study of hardening is also interesting from a preventive perspective, and further studies with longer exposure time should clarify this aspect.

In the current study, re-exposure to SLS was performed with Finn Chambers (12 mm), so that a larger area was exposed to the irritant, to obtain reproducibility of test results. A previous study has shown that TEWL measurements are biased when performing irritant patch testing with Finn chambers (8 mm), because the adjacent small area of non-treated skin is also assessed by the evaporimeter, the surface area of the probe being too large, 1 cm² (21). Knowledge of the irritant potential of commonly available detergents and disinfectants is important in relation to ICD. Consequences of chronic ICD in hospital staff to the health care system are large and probably still underestimated (22). The current study clearly illustrates that short-term exposure to detergents causes more skin irritation than disinfectant and combination of disinfectant/detergent. Further studies continuing the irritant exposure over a longer period of time are necessary before recommendations can be made. In this study, we concentrated on irritant effects of soaps and disinfectants only, and their antimicrobial effects have not been evaluated. With respect to hardening, this was not obtained after 4 weeks from this mild- and short-term exposure.

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References

1. Lodén M, Buraczewska I, Edlund F. The irritation potential and reservoir effect of mild soaps. *Contact Dermatitis* 2003; 49: 91–96.
2. Rotter M L. Hand washing and hand disinfection. In: *Hospital and Epidemiology and Infection Control*, Mayhall G C, (ed.). Philadelphia: Lippincott Williams & Wilkins 1999: 1339–1355.
3. Zaragoza M, Sallés M, Gomez J, Bayas J M, Trilla A. Handwashing with soap or alcoholic solutions? A randomised clinical trial of its effectiveness. *Am J Infect Control* 1999; 3: 258–261.
4. Pietsch H. Handantiseptics: Rubs versus scrubs, alcoholic solutions versus alcohol gels. *J Hosp Infect* 2001; 48: 33–36.
5. Winnefield M, Richard M A, Drancourt M, Grob J J. Skin tolerance and effectiveness of two hand decontamination procedures in everyday hospital use. *Br J Dermatol* 2000; 143: 546–550.
6. Boyce J M. Using alcohol for hand antisepsis: dispelling old myths. *Infect Control Hosp Epidemiol* 2000; 21: 438–441.
7. Boyce J, Kelliher S R N, Vallande N, M S. Skin irritation and dryness associated with two hand-hygiene regimens: Soap and water hand washing versus hand antisepsis with an alcoholic gel. *Infect Control Hosp Epidemiol* 2000; 21: 442–448.
8. Boyce J M, Pittet D. 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. *Infect Control Hosp Epidemiol* 2002; 23: 1–40.
9. Goh C L. The role of skin moisturizers in the prevention of irritant contact dermatitis: A review. In: *Condensed Handbook of Occupational Dermatology*, Kanerva L, Elsner P, Wahlberg J E, Maibach H I, (eds). Heidelberg: Springer-Verlag 2004: 271–277.
10. Larson E, Allison A E, Bastyr J, Lyle Stahl J, Cronquist Alicia Lai L, Latta-Della P. Assessment of two hand hygiene regimen for intensive care unit personnel. *Crit Care Med* 2003; 29: 944–951.
11. Held E, Mygind K, Wolff C, Gyntelberg F, Agner T. Prevention of work related skin problems: An intervention study in wet work employees. *Occup Environ Med* 2002; 59: 556–561.
12. Stingeri L, Lapomada V, Lisi P. Occupational hand dermatitis in hospital environments. *Contact Dermatitis* 1995; 33: 176.
13. Kappes U P, Goritz N, Wigger-Alberti W, Heinemann C, Elsner P. Tandem application of sodium lauryl sulfate and n-propanol does not lead to enhancement of cumulative skin irritation. *Acta Derm Venereol* 2001; 81: 403–405.
14. Wigger-Alberti W, Krebs A, Elsner P. Experimental irritant contact dermatitis due to cumulative epicutaneous exposure to sodium lauryl sulphate and toluene: single and concurrent application. *Br J Dermatol* 2000; 143: 551–556.
15. Frosch P J, Kligman A M. The soap chamber test. A new method for assessing the irritancy of soaps. *J Am Acad Dermatol* 1979; 1: 35–41.
16. Pinnagoda J, Tupker R A, Agner T, Serup J. Guidelines for transepidermal water loss (TEWL) measurement. A report from the Standardization Group of the European Society of Contact Dermatitis. *Contact Dermatitis* 1990; 22: 164–178.
17. Fullerton A, Fischer T, Lahti A, Wilhelm K P, Takiwaki H, Serup J. Guidelines for measurement of skin colour and erythema. A report from the Standardization Group of the

- European Society of Contact Dermatitis. *Contact Dermatitis* 1996; 35: 1–10.
18. Hindsen M, Bruze M. The significance of previous contact dermatitis for elicitation of contact allergy to nickel. *Acta Derm Venereol* 1998; 78: 367–370.
19. Freeman S, Maibach H. Study of irritant contact dermatitis produced by repeated patch test with sodium lauryl sulfate and assessed by visual methods, transepidermal water loss, and laser Doppler velocimetry. *J Am Acad Dermatol* 1988; 19: 496–502.
20. Widmer J, Elsner P, Burg G. Skin irritant reactivity following experimental cumulative irritant contact dermatitis. *Contact Dermatitis* 1994; 30: 35–39.
21. Löffler H, Freyschmidt-Paul P, Effendy I, Maibach H I. Pitfalls of irritant patch testing using different test chamber sizes. *Am J Contact Dermat* 2001; 12: 28–32.
22. Heeg P. Does hand care ruin hand disinfection? *J Hosp Infect* 2001; 48: S37–S39.

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