

Effect of glove occlusion on human skin.

(I). Short-term experimental exposure

DORTE W. RAMSING AND TOVE AGNER

Department of Dermatology, Gentofte Hospital, University of Copenhagen, Denmark

Skin barrier function was studied after use of occlusive gloves on normal and compromised skin. 2 studies were performed (Study A and B), and the effects were evaluated by non-invasive methods. Participants in the studies were instructed to wear an occlusive glove on one hand, while the other hand served as control. The gloves used were hypoallergenic, non-latex. Study A: 20 volunteers wore a glove on normal skin 6 h/day for 3 days. Study B: 20 volunteers wore a glove on sodium lauryl sulfate (SLS)-compromised skin 6 h/day for 3 days. Skin barrier function was evaluated by measurement of transepidermal water loss (TEWL) (Evaporimeter), skin hydration by electrical capacitance (Corneometer) and inflammation was evaluated by erythema index (DermaSpectrometer). Results: Study A. Glove occlusion on normal skin 6 h/day for 3 days caused no significant influence on the water barrier function. Study B: Glove occlusion on SLS-compromised skin for the same period of time had a significantly negative effect on the water barrier function. It is concluded that occlusion may be an additional factor in the pathogenesis of cumulative irritant contact dermatitis.

Key words: occlusion; gloves; skin barrier function; irritation; sodium lauryl sulfate; wet work; bioengineering methods. © Munksgaard, 1996.

Accepted for publication 28 March 1995

The water permeability barrier of the skin is regulated primarily by the lamellar arrangement of the lipid bilayers. Disruption of the barrier normally results in stimulation of DNA and an increase in the synthesis of free fatty acids, sphingolipids and cholesterol, leading to barrier repair (1). Experimental studies in mice have shown a delayed epidermal barrier repair during occlusion (2), and occlusion has also been reported to influence cytokine production in murine skin (3). Experimental studies of human skin have, however, provided conflicting results on the effect of occlusion on skin barrier function (4, 5).

Glove-related skin irritation was reported in 2 recently published studies based on questionnaires among dental and hospital personnel, with 29% and 37%, respectively, complaining of this symptom (6, 7). However, protective gloves provide a necessary protection against irritants and allergens as well as microbiological agents. The aim of the present study was to examine the effect of glove occlusion on human skin with respect to skin barrier function. Another aim was to follow water evaporation immediately after glove removal, in order to validate the correct time for measurements. In wet work, exposure to water and deter-

gents in combination with gloves is common. The study was performed on normal skin, and, to imitate the daily life situation in wet occupations, also on sodium lauryl sulfate (SLS)-compromised skin (8, 9). The study was performed on the hands, which are the most common site for irritant contact dermatitis (ICD).

Materials and Methods

Two studies (A and B) were performed. 20 healthy volunteers (all female, median age 44 (range 24-61 years), were included in study A, and 20 healthy volunteers (17 female, 3 male, median age 43 (range 33-62 years)), were included in study B. The volunteers were recruited among the nurses at the hospital. Informed consent was obtained from all subjects and the studies were approved by the local ethical committee. Subjects sensitized to ubiquitous allergens, subjects with previous hand eczema, and subjects with an anamnesis of atopic dermatitis were not included. The volunteers in the studies were randomized to wear an occlusive glove on either left or right hand, while the other hand served as control. The gloves were hypoallergenic, non-latex gloves (Elastyren), and they were worn

at night, both for practical reasons, and to ensure that the control hand was not exposed to soaps, creams, etc.

Study A. The volunteers wore an occlusive glove on one hand for a minimum of 6 h/day for 3 days. Evaluation was performed before the use of glove (baseline) and in the morning on day 3, $\frac{1}{2}$ h, 1 h, 2 h, 3 h after removal of the glove.

Study B. The volunteers had both hands immersed in a 0.5% aqueous SLS solution (SLS: Sigma >99% purity), temperature 35°C (range 32.4–36.1°C). Immersion took place for 10 min $2 \times$ daily for two days, with an interval of at least 4 h between immersions (8). If clinical reactions appeared, immersions were stopped. When all 4 immersions were completed, the volunteers were instructed to wear an occlusive glove on one hand for a minimum of 6 h/day for 3 days. A minimum interval of 6 h was assured between the last immersion and donning the glove. Evaluation was performed at baseline (day 1), after ending immersion (day 2), after ending glove exposure (day 5) and at follow-up (day 7). A period of at least 3 h between removal of the glove and measurements was assured.

The volunteers were not allowed to use any kind of moisturizers, but were allowed to wash hands normally, ensuring that the hands were equally exposed. 3 test sites were chosen for measurements, placed on the radial, central and ulnar part of the dorsum of the hands, avoiding the veins. Evaluation was performed with the following noninvasive methods:

Transepidermal water loss (TEWL) was measured by an Evaporimeter EP1 (Servo Med, Stockholm, Sweden), according to the Guidelines of the Standardization Group of the European Society of Contact Dermatitis (10). Details of the operating principle of the Evaporimeter are described elsewhere (11).

Electrical capacitance was measured by a Corneometer CM 820^R, as a measure of the hydration of stratum corneum (12, 13).

Erythema index was measured using a DermaSpectrometer (Cortex Technology, Hadsund, Denmark). This method is based on the amount of red and green light reflected from the skin (14). The spectrometer was placed in contact with the site to be measured, with minimal pressure on the skin.

Measurements were performed following a relaxation period of 15–30 min. The relative humidity varied between 24–58%, ambient temperature was kept at 20–22°C and the skin temperature measured on the test region was 29.9 (25/75 percentiles were 28.5–30.6, respectively). The study was performed during the winter months of 1993/

1994. Measurements are expressed as the mean values of the recordings of evaporimetry, electrical capacitance and erythema index on the 3 test sites on the back of each hand.

Statistics

The Wilcoxon test for paired samples modified according to Pratt was used for comparative studies. $p < 0.05$ was chosen as level of significance. Results are given as medians and 25/75 percentiles.

Results

Study A

TEWL (Fig 1)

TEWL was significantly increased on the occluded hand compared to the control hand, when measured 30 min after removal of the glove ($p < 0.001$). No significant difference was observed between the hands at baseline or 1 h, 2 h and 3 h after removal of the glove. A positive but not significant difference in favour of control hand was observed at baseline, therefore TEWL values were analysed in the form of differences from baseline. This gave the same result as above with significant difference between the hands 30 min after removal of the glove and no significant difference between the hands 1 h, 2 h and 3 h after removal of the glove.

Electrical capacitance (Table 1)

Electrical capacitance did not change significantly during the study, and no significant differences were observed between the hands.

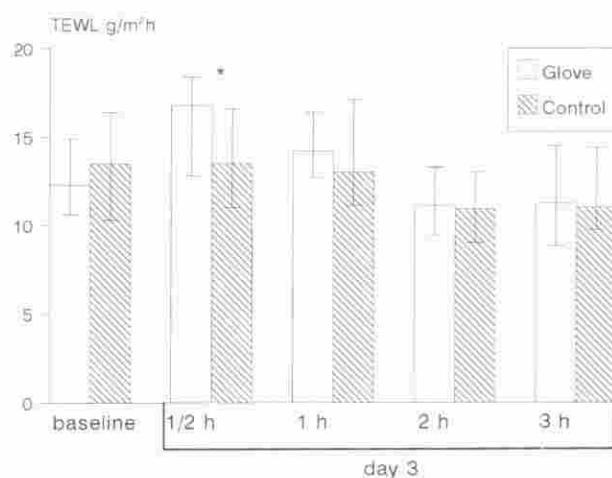


Fig. 1. Study A. Median values and 25/75 percentiles of transepidermal water loss (TEWL) at baseline and on day 3 $\frac{1}{2}$ h, 1 h, 2 h, and 3 h after removal of the glove. TEWL was significantly increased $\frac{1}{2}$ h after removal of the glove; * $p < 0.001$. No significant difference between the hands was observed at baseline, after 1 h, 2 h and 3 h.

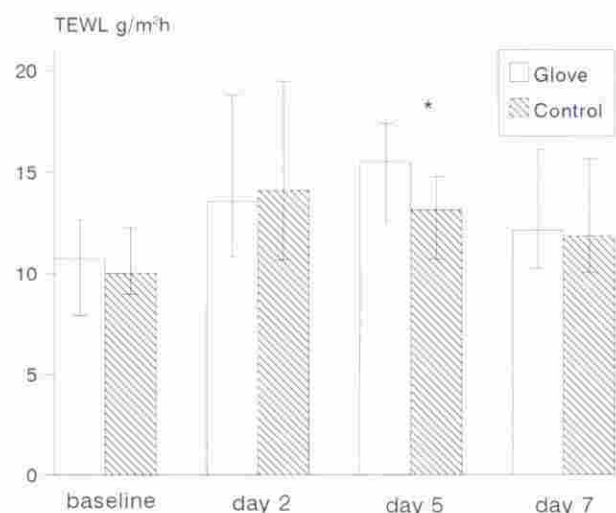


Fig. 2. Study B. Median values and 25/75 percentiles of transepidermal water loss (TEWL) at baseline, after 4 immersions (day 2), after glove occlusion on one hand (day 5) and at follow-up (day 7). TEWL increased significantly on the occluded hand compared to the control hand after use of the glove (day 5); * $p < 0.01$. No significant difference between the hands was observed at baseline and on days 2 and 7.

Erythema index

Erythema index was significantly lower on the occluded hand compared to control hand 1 h after removal of the glove ($p < 0.01$). No significant difference was observed between the hands at baseline, or after $\frac{1}{2}$, 2 and 3 h (data not shown).

Clinical observations

Just after occlusion, 70% had a spongy and white appearance on the occluded hand, which disappeared within the 1st hour after removal of the glove.

Study B

TEWL (Fig. 2)

A significant increase was observed in TEWL on both hands after SLS-immersion ($p < 0.001$). After the use of an occlusive glove (day 5), TEWL was significantly higher compared to the control hand ($p < 0.01$). An increase was observed in TEWL on the occluded hand from day 2 to day 5, while a decrease was observed on the control hand from day 2 to day 5, although these changes in TEWL from day 2 to day 5 did not reach statistical significance. TEWL values were without significant differences between the hands at baseline (day 1), after immersion (day 2), and at follow-up (day 7). A positive but not significant difference in favour of glove hand was observed at baseline, therefore

Table 1. Study A: electrical capacitance (arbitrary units). Median values and 25/75 percentiles

	Occluded hand	Control hand	
baseline	62.0 (54.5–69.3)	63.5 (59.3–70.5)	ns
day 3 $\frac{1}{2}$ h	56.0 (53.3–63.8)	58.0 (50.0–65.8)	ns
day 3 1 h	57.5 (51.5–69.0)	60.0 (49.3–66.5)	ns
day 3 2 h	60.0 (52.5–65.5)	58.5 (52.3–64.8)	ns
day 3 3 h	61.5 (55.5–69.0)	58.5 (54.5–65.0)	ns

Table 2. Study B: electrical capacitance (arbitrary units). Median values and 25/75 percentiles

	Occluded hand	Control hand	
baseline	66.2 (58.3–75.3)	66.5 (55.3–73.5)	ns
day 2	44.5 (35.0–52.5)	44.0 (37.8–50.0)	ns
day 5	55.5 (51.3–68.5)	54.0 (43.5–61.8)	$p < 0.002$
day 7	55.5 (47.0–65.8)	53.0 (43.5–65.5)	ns

TEWL values were analysed in the form of differences from baseline. This gave the same result as above, with significant difference between the hands at day 5 and no significant difference at day 2 and day 7.

Electrical capacitance (Table 2)

A significant decrease was observed in electrical capacitance on both hands after immersion ($p < 0.001$). A significant difference was observed between the hands after the use of an occlusive glove (day 5), with higher values on the occluded hand compared to the control hand ($p < 0.002$). Electrical capacitance was without significant difference between the hands at baseline (day 1), after immersion (day 2) and at follow-up.

Erythema index

Erythema index was not significantly influenced after immersion, nor by occlusion. No significant difference was found between the hands during the study (data not shown).

Clinical observations

All volunteers were able to complete the 4 immersions without developing clinical symptoms. Slight dryness was observed after immersion ended. Following occlusion, 4 volunteers developed dryness with scaling and slight erythema, and 1 volunteer developed erythema with small papules on the occluded hand.

Discussion

The study illustrates that glove occlusion on SLS-compromised skin 6 h/day for 3 days further com-

promises skin barrier function and delays barrier regeneration. Barrier function of normal skin was, however, not significantly affected by occlusion for the same period of time.

In study A, the time course of TEWL after removal of the glove was studied. TEWL was significantly increased 30 min after glove removal. This reflects temporary water evaporation following occlusion, and is in agreement with an earlier study on the effect of patch test occlusion, which also found increased TEWL values 30 min after removal of an empty patch test chamber (15). No significant difference between the hands was found after 1 h. However, TEWL values were still declining from 1–2 h after glove removal, and values were not stabilised until 2–3 h after occlusion ended; indicating that TEWL values at this point reflect the water barrier function of the skin.

Although a relaxation period of at least 15 min was assured, a decrease was observed on both hands from 1 h to 2 h. The measuring situation might have influenced the volunteers, who may have become more at ease after 2 h. The paired observations used in the study assure that interindividual changes are accounted for. No difference in TEWL was found between the glove hand and the control hand after 3 h, indicating that occlusion 6 h/day for 3 days does not significantly influence the barrier function of normal skin.

The decreased erythema index value found 1 h after removal of the occlusive glove in study A, corresponds well to the clinical observation of a spongy appearance of the occluded hand. This could possibly reflect increased water binding of stratum corneum.

Occlusion 6 h/day for 3 days had a significantly negative effect on the barrier function of primarily irritated skin, when measured by TEWL in study B. The further deterioration of the barrier function could be related to occlusion itself, to an intensified effect of SLS under occlusion, or to a combination of these 2 factors. That the effect can be related to occlusion is supported by experimental studies. Proksch et al. (2) illustrated how disturbances in the barrier function in mice lead to an increase in the synthesis of DNA and lipids (barrier repair mechanism). This barrier repair was prevented by latex occlusion, representing an artificial barrier repair. The delayed barrier repair under occlusion in humans has only been investigated in a few studies. Wenzel et al. (5) found no delay in barrier repair under occlusion, neither in tape-stripped nor in SLS-irritated human skin. On the contrary, it was indicated in a recent study by Graves et al. (4) that occlusion for 2 days increased TEWL. TEWL values remained elevated the day after removal of an occlusive glove, indicating a

possible hazardous effect of the gloves. This finding was not confirmed in our present study. Differences in set-up and time of measurements could account for the discrepancy in results. The cellular mechanism in the human skin barrier after occlusion is barely known. Kligman (16) found ultrastructural injury to keratinocytes, fibroblasts, Langerhans cells and endothelium after a few days of occlusion without any clinical changes. Repair of trauma to compromised and apparently normal skin may be disrupted or delayed by occlusion. Further studies are needed with respect to the skin barrier function after occlusion, including ultrastructural investigations.

An intensified effect of SLS under occlusion could be another explanation for the increased TEWL after occlusion found in study B. Although a period of 6 h was assured between the last immersion and donning the glove, some SLS might still be present in the skin. A recently published *in vitro* study on human cadaver skin demonstrated that penetration of SLS continued after removal of a 24 h SLS patch test, and that SLS was still present in the epidermis after 48 h (17). Occlusion after SLS exposure was previously found to increase the irritant effect of SLS (18), and this could explain the further deterioration of the skin barrier function following occlusion. These observations could be of relevance for the situation in wet occupations. A study by our group found no penetration of ³⁵S-SLS through 6 different gloves (19). However, exposure to soap-containing detergents before gloves are used may still be present on the skin, and thus intensify skin irritation.

Electrical capacitance increased significantly after the use of an occlusive glove on compromised skin compared to the control hand (study B). The increased electrical capacitance reflects an increased state of hydration of the stratum corneum on the occluded hand (20).

The immersion model of compromised skin (8), used in the present study, was found to be a useful model to compromise subclinically the skin barrier function on the hands. Risk of sensitization and reactions to the glove material were minimized by the use of a hypoallergenic non-latex glove. Wrangsjö et al. (7) reported that 47% of operating personnel used gloves for more than 4 h daily, and also among dental personnel usage of gloves for several hours was common (82.8%) (6). In our study a daily exposure of 6 h was chosen.

In conclusion, glove occlusion for 3 days further aggravated the barrier function of compromised skin, whereas no effect was found on normal skin. Occlusion itself may have a negative effect on the skin barrier, which may only be revealed on already compromised skin, or possibly by occlusion

for a longer period of time. It is illustrated that exposure to detergents prior to the use of occlusive gloves may aggravate their irritant effects, and working procedures should be considered with respect to this observation. The results indicate that occlusion may be an additional factor in the pathogenesis of cumulative ICD. Further studies with long-term occlusion should be made.

References

1. Feingold K R, Mao-Qiang M, Proksch E, Menon G K, Brown B E, Elias P M. The Lovostatin-treated rodent: a new model of barrier disruption and epidermal hyperplasia. *J Invest Dermatol* 1991; vol 96: 201-209.
2. Proksch E, Holleran W M, Menon G K, Elias P M, Feingold K R. Barrier function regulates epidermal lipid and DNA synthesis. *Br J Dermatol* 1993; 128: 473-482.
3. Wood L C, Elias P M, Sequeria-Martin S, Grunfeld C, Feingold K R. Occlusion lowers cytokine mRNA levels in essential fatty acid-deficient and normal mouse epidermis, but not after acute barrier disruption. *J Invest Dermatol* 1994; 103: 834-838.
4. Gaves C J, Edwards C, Marks R. The occlusive effects of protective gloves on the barrier properties of stratum corneum. *Allergologie* 1994; 17: 109.
5. Welzel J, Wilhelm K P, Wolff H H. Occlusion does not influence the repair of the permeability barrier in human skin. *Allergologie* 1994; 17: 115.
6. Burke F J T, Wilson N H F, Cheung S W. Factors associated with skin irritation of the hands experienced by general dental practitioners. *Contact Dermatitis* 1995; 32: 35-38.
7. Wrangsjö K, Osterman K, van Hage-Hamsten M. Glove-related skin symptoms among operating theatre and dental care unit personnel. (I). Interview investigation. *Contact Dermatitis* 1994; 30: 102-107.
8. Allenby C F, Basketter D A, Dickens A, Barnes E G, Brough H C. An arm immersion model of compromised skin. *Contact Dermatitis* 1993; 28: 84-88.
9. Klein G, Grubauer G, Fritsch P. The influence of daily dish-washing with synthetic detergent on human skin. *Br J Dermatol* 1992; 127: 131-137.
10. Pinnagoda J, Tupker R A, Agner T, Serup J. Guidelines for transepidermal water loss (TEWL) measurement. *Contact Dermatitis* 1990; 22: 164-178.
11. Nilsson GE. On the measurement of evaporative water loss. Linköping University Medical dissertations no. 48, 1977.
12. Barel A O, Clarys P. Measurement of epidermal capacitance. In: Serup J, Jemec G B E (eds): *non-invasive methods and the skin*. Boca Raton, Florida: CRC, 1995.
13. Agner T. Noninvasive measuring methods in the study of irritant patch test reactions. *Acta Dermato-venereologica* 1992; suppl 173.
14. Farr P M, Diffey B L. Quantitative studies on cutaneous erythema induced by ultraviolet radiation. *Br J Dermatol* 1984; 111: 673-682.
15. Agner T, Serup J. Time course of occlusive effects on skin evaluated by measurement of transepidermal water loss (TEWL). *Contact Dermatitis* 1993; 28: 6-9.
16. Kligman A M. Hydration: a confounding factor in patch testing. Abstract, presented at the *International Symposium on Irritant contact dermatitis*, Gronningen, Holland, 3-5 October, 1991.
17. Fullerton A, Broby-Johansen U, Agner T. Sodium lauryl sulphate penetration in an in-vitro model using human skin. *Contact Dermatitis* 1994; 30: 222-225.
18. Van der Valk P G M, Maibach H I. Post-application occlusion substantially increases the irritant response of the skin to repeated short-term sodium lauryl sulfate (SLS) exposure. *Contact Dermatitis* 1989; 21: 335-338.
19. Ramsing D, Fullerton A. Permeability of protective gloves to sodium lauryl sulfate. *Skin Research and Technology* 1995: submitted.
20. Walters K A, Bialk W, Brain K R. The effect of surfactants on penetration across the skin. *Int Jour Cosm Science* 1993; 15: 260-270.

Address:

Dorte W. Ramsing
Department of Dermatology
Gentofte Hospital
Niels Andersens Vej 65
DK-2900 Hellerup
Denmark

This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.