

Human scalp irritation compared to that of the arm and back

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Large-scale data comparing reactions to surfactants between scalp and back and arm are lacking. The sensitivity of responses between scalp and back and arm were explored utilizing an open-application model for testing the potential irritancy of sodium lauryl sulphate (SLS). 10 bald male Caucasians (mean age 56 ± 9 years) were enrolled. We conducted 5 successive washings: for each wash, the technician pipetted 1 ml of 20% SLS solution into a glass cylinder placed on the designated area with hand pressure that prevented the cylinder leaking. The test area was then rubbed with a Teflon Policeman scrubber for 1 min. Post scrubbing, the solution was absorbed dry with a plastic pipette and blotted by gently applying paper tissues. After a 5-min rest, the procedure was repeated for 4 more times for a total of 5 times. Skin-irritancy assessments by visual scoring and instrumental measurements were made at 30 min and 24 h thereafter and squamometry at the end of last washing. Results indicated that most parameters revealed that the back was most sensitive to the SLS challenge. Thus, these data support the current standard skin-compatibility testing procedure, employing the back for potential irritation testing of hair care products.

Key words: hair care products; intercorneocyte cohesion; sodium lauryl sulphate (SLS); squamometry; transepidermal water loss (TEWL). © Blackwell Munksgaard, 2004.

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Large-scale irritation tests for dermatologic and cosmetic products have been conducted on the back and arm. Like the face, the scalp is frequently a target of topical products such as drugs and cosmetics. Yet, shampoos often contain potential irritants. The scalp may hide classical irritation morphology (erythema and oedema). However, few investigations document the scalp's structure and functions (1–3). In particular, data comparing reactions to surfactants between scalp and back and arm are lacking.

Typical exposure to surfactants by the consumer is repetitive, for brief periods, and via open application, such as hand washing or personal cleansing. Therefore, commonly used patch tests that utilize surfactants under occlusive condition to determine irritation potential may not express their irritation potential under typical consumer use conditions. An open-test method that mimics real life application of surfactants is required.

This study utilized our previously established open-application model (4) with a modification to testing potential irritancy of a 'gold standard' model irritant, SLS on human scalp (5). The sen-

sitivity of responses between scalp and back and arm were also explored.

Materials and Methods

Subjects

10 healthy, Caucasian, adult bald men (mean age 56 ± 9 years) were enrolled. Subjects were healthy with no obvious skin disease or known history of atopic dermatitis. The University of California at San Francisco Human Research Committee approved this study.

Surfactant

SLS (99% purity, Sigma Chemical Co., St. Louis, MO, USA) was freshly prepared in deionized water at 20% (W/W) concentration.

Experimental design

This study was randomized (each test area was chosen in a random manner). Each volunteer served as his own control between the different test regions.

General procedure

3 test areas were designated separately on volar forearm, upper back and scalp. The designated test area was approximately 3 cm². Basal values of instrumental measurements were taken on each test site prior to SLS treatment. A technician conducted 5 successive washing: for each wash, the technician pipetted 1 ml of 20% SLS solution into a glass cylinder (2 cm of diameter) placed on the designated area with hand pressure that prevented the cylinder leaking. The test area was then rubbed with a Teflon Policeman scrubber (Fisher Scientific, Pittsburgh, PA, USA) for 1 min. At the end of scrubbing, the solution was absorbed dry with a plastic pipette and then the test area was blotted by gently applying paper tissues. After a 5-min rest, the procedure was repeated for 4 more times for a total of 5 times. Skin-irritancy assessments by visual scoring and instrumental measurements were made at 30 min and 24 h thereafter.

At the end of all measurements, 1 stripping of stratum corneum was taken by using tape discs (D-squame[®], Cuderm Corporation, Dallas, TX, USA) from each test area. Additionally, 3 untreated (normal) skin areas were stripped with D-squame[®] disc as blank controls from the volar forearm, upper back and scalp of each subject. These discs were for the squamometric analysis. Details of squamometric analysis are described previously (4, 6–8).

Visual scoring (VS)

VS was judged according to the following rating scale (4–8): Erythema: 0 = no redness; 1 = very slight redness; 2 = slight redness; 3 = moderate redness; 4 = strong redness; 5 = very strong redness; 6 = extreme redness.

Instrumental measurements

Transepidermal water loss (TEWL) was assessed by a Tewameter (TM 210, Courage & Khazaka, Cologne, Germany, and Acaderm Inc., Menlo Park, CA, USA). TEWL documents integrity of stratum corneum water-barrier function and is a sensitive measure of surfactant-induced skin-barrier alteration (9). The measuring principle and standard guidelines are published (10). TEWL values were expressed as g/m²/h.

Skin capacitance was measured by a Cornometer (CM 820, Courage & Khazaka and Acaderm Inc.). Capacitance is a parameter of stratum corneum hydration (or water content). The measuring principle and methods are described elsewhere (11). It was expressed digitally in arbitrary units (a.u.).

Erythema was quantified by skin colour reflectance measurements using a colourimeter (Chroma Meter CR 300, Minolta, Osaka, Japan, and Acaderm Inc.). The a* value represents the colour spectrum from total green to pure red and correlates closely with erythema (9, 12). Standard guidelines and measuring principles have been published in detail (13).

The measurements were conducted in a room with daily ranges of relative humidity (RH) from 50.8 ± 3.8% and temperature from 20.1 ± 1.3°C. These values (RH and °C) were recorded during the experimental period. Each subject rested at least 30 min for acclimation before measurements.

Statistical analysis

Statistics were performed using a computer program SIGMASTAT[®] (SPSS Science, Chicago, IL, USA). One-way repeated-measures ANOVA evaluated the differences for values of TEWL, capacitance, and a*. *T*-test was performed with values of C*. The Friedman-repeated measures were performed for the non-parametric visual scores (erythema). Wilcoxon-signed rank test was performed for the non-parametric data (intercorneocyte cohesion and amount and distribution of dye found in cells). All tests of comparisons were 2-sided at a significance level of 0.05.

Results

Visual scores (VS)

VS was significantly increased ($P < 0.05$) on the back in comparison to the forearm at both time points of 30 min and 24 h post SLS treatment. The VS on the scalp was higher than on the forearm but did not reach statistical significance.

Instrumental evaluations

a values. a* was significantly increased ($P < 0.05$) on the back in comparison to the forearm as well as to the scalp at the time points of 30 min and 24 h post SLS treatment (Fig. 1). a* showed a slight increase on the scalp when compared to the forearm but did not reach statistical significance.

TEWL. TEWL was significantly increased ($P < 0.05$) on the back in comparison to the forearm at 30 min post SLS treatment (Fig. 2). After 24 h, there were no statistically significant differences between the sites.

Capacitance. Capacitance was significantly changed ($P < 0.05$) on the back in comparison to the forearm at 30 min post SLS treatment. Also, capacitance was significantly changed ($P < 0.05$)

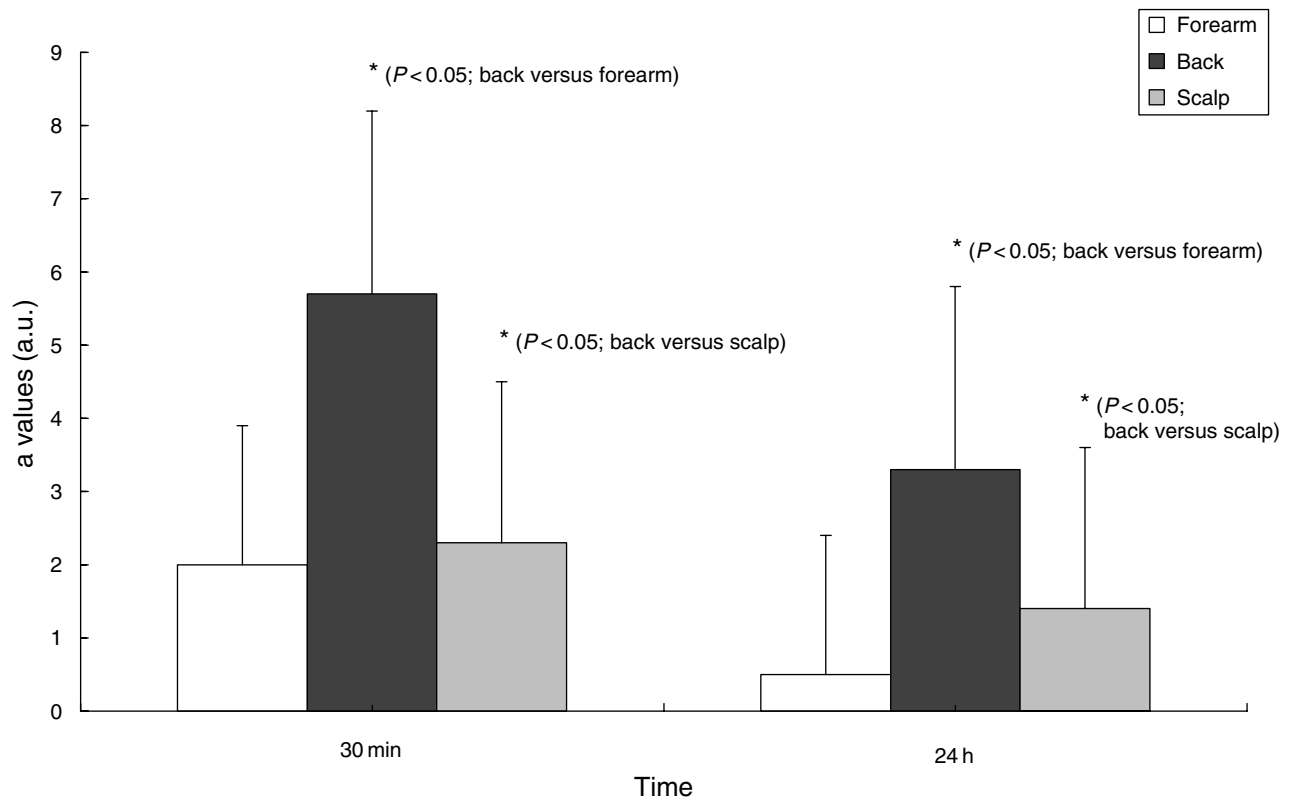


Fig. 1. Comparison of a^* at different regions at 30 min and 24-h post SLS-treatment (data were subtracted from baseline).

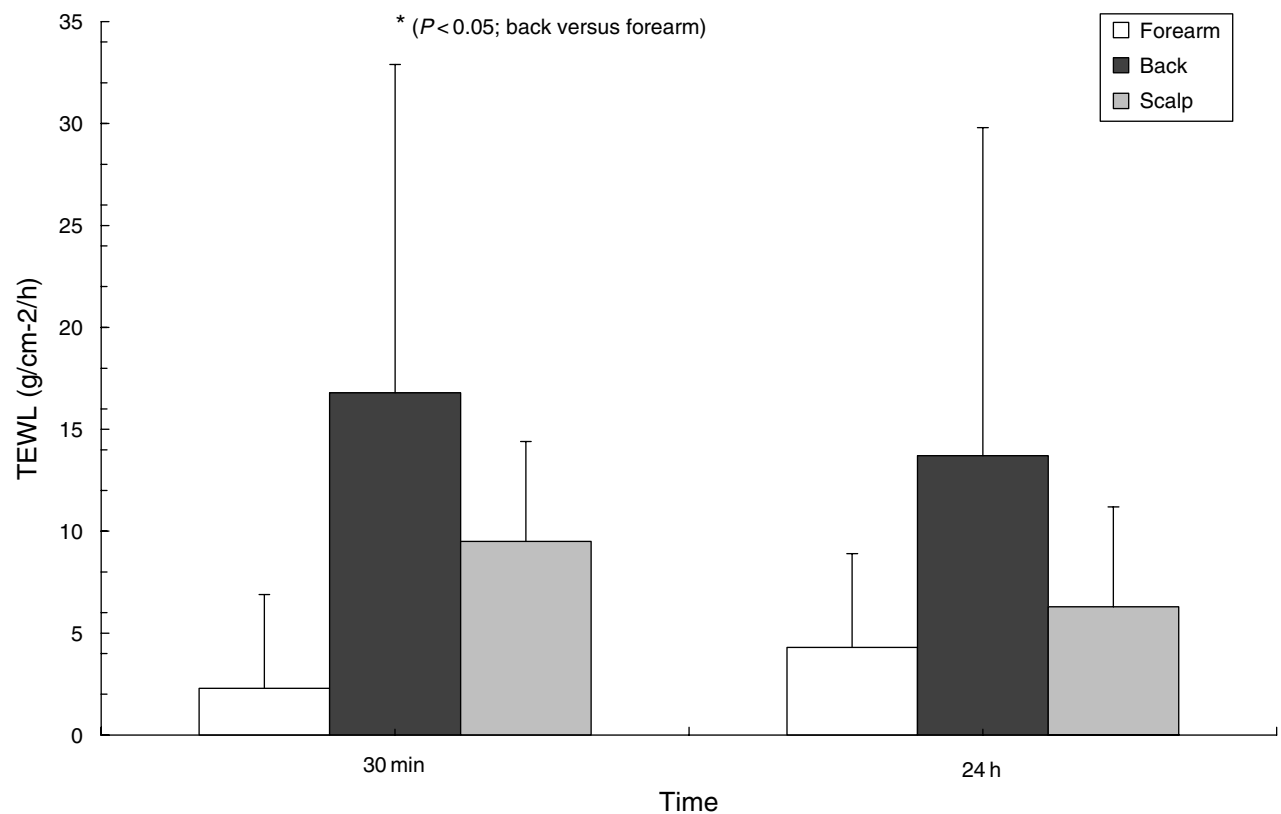


Fig. 2. Comparison of TEWL at different regions at 30 min and 24-h post SLS-treatment (data were subtracted from baseline).

on the scalp in comparison to the forearm at 30 min post SLS treatment. After 24 h, there were no statistical significant differences between the sites.

Chroma C*. The Chroma C* was significantly increased ($P < 0.05$) on the SLS-treated sites in comparison to control sites (normal skin) except on the back.

Squamometry

Dye fixation. The dye fixation at all SLS-treated sites was significantly increased ($P < 0.05$) in the cells in comparison to control sites (normal skin).

Cohesion assessment. All SLS-treated sites showed a significantly greater loss of cell cohesion ($P < 0.05$) in comparison to control sites (normal skin).

Change ratio % and sensitivity to SLS treatment

The 'Change ratio %' was calculated with the following formula:

$$\begin{aligned} \text{Change ratio \%} &= (\text{treatment} - \text{baseline}) / \\ &\quad \text{baseline} \times 100\% \text{ or} \\ &= (\text{time point post treat-} \\ &\quad \text{ment} - \text{baseline}) / \text{base-} \\ &\quad \text{line} \times 100\% \end{aligned}$$

Table 1 summarizes the change ratio % of all parameters. Rank of changes (sensitivity) to SLS treatment for a* from different regions: at 30 min post treatment was back > forearm > scalp; after 24 h post treatment was back > scalp > forearm. Rank of changes (sensitivity) for TEWL: at 30 min post treatment was back > scalp > forearm; after 24 h post treatment was back > scalp > forearm. Rank of changes (sensitivity) for capacitance: at 30 min post treatment was scalp > forearm > back; after 24 h post treatment was back > forearm > scalp. Rank of changes (sensitivity) for Chroma C* was forearm > scalp > back. Rank of changes (sensitivity) for dye was forearm > scalp > back. Rank of changes (sensitivity) for cohesion was back > scalp > forearm.

Table 1. Change ratio percentage of all parameters

		Forearm	Back	Scalp
a values	30 min	20.0	66.3	18.5
	24 h	5.0	38.4	11.3
TEWL	30 min	30.6	240.0	99.0
	24 h	58.3	195.7	66.7
Capacitance	30 min	-11.0	5.9	14.1
	24 h	3.0	4.9	-1.0
Chroma C*		67.7	20	38.5
Dye		76.9	31.6	68.8
Cohesion		140.0	233.3	190.0

Discussion

Male-pattern baldness (androgenetic alopecia) is a common hair-loss disorder. Kligman (14) noted histopathological inflammatory changes in the upper dermis in male-pattern baldness, but most of the skin surface is clinically devoid of inflammatory change. Furthermore, O'goshi et al. (2) confirmed that stratum corneum function of the skin in male-pattern baldness was intact without any impairment in terms of barrier function or water-holding capacity. Hence, we chose these subjects as a suitable model to determine the response to SLS on their scalp.

In this study, most parameters (VS, a*, TEWL and cohesion) showed that the back was most sensitive to SLS challenge. Thus, these results support the current standard skin-compatibility testing procedure, employing the back for potential irritation testing of hair-care products. However, capacitance data were complicated to interpret because this mainly reflects skin hydration rather than impairment of the water barrier. A previous study indicated that removing skin-surface lipids from the scalp and forearm by acetone markedly reduced skin-surface hydration values (2).

Squamometry, a sensitive assessment for detecting surfactant-induced subclinical irritation (4, 6-8), demonstrates superiority in evaluation of efficacy of moisturizers and barrier creams against a surfactant irritant (15, 16), as well as in screening hydrating products (17). Data of dye and Chroma C* were consistent but different from cohesion, because there are 2 mechanisms between cohesion and dye fixation: cohesion with protein and lipid metabolism; dye fixation with protein only (4). For example, if the surfactant has sufficient solvating properties, it might influence cohesion. Another point is the way that surfactants are applied. When applying the tested surfactant by washing, the surfactant might cut the cells (protease mechanism) in the first layers (because of its irritancy) and the friction of the wash-remove cells; then they are removed with the rinse procedure.

Recent data indicated that there was no difference in the biophysical parameters obtained for the barrier function or water-holding capacity of the stratum corneum between lesional skin of alopecia areata and freshly-shaved scalp skin (2). In general, investigations on the functional aspects between bald scalp and shaved healthy scalp skin are limited. We have minimal data on thresholds for irritation at varying anatomic sites. Percutaneous penetration (18) and irritation (19) differs from site to site. We would assume that

irritation thresholds also differ but have an inadequate database to so confirm. Data having been obtained for acute irritation with a hydrophilic surfactant, cannot be, at this time, equated with either hydrophobics or other mechanisms (sensory irritation, cumulative irritation or allergic contact dermatitis). Because this was testing on the scalp of male-pattern baldness subjects, we do not wish to overinterpret the data to the hairy scalp. This information provides the potential for planning the next level of use-type study.

References

1. Ya-Xian Z, Suetake T, Tagami H. Number of cell layers of the stratum corneum in normal skin – relationship to the anatomical location on the body, age, sex and physical parameters. *Arch Dermatol Res* 1999; 291: 555–559.
2. O'goshi K, Iguchi M, Tagami H. Functional analysis of the stratum corneum of scalp skin: studies in patients with alopecia areata and androgenetic alopecia. *Arch Dermatol Res* 2000; 292: 605–611.
3. Warner R R, Schwartz J R, Boissy Y, Dawson T L Jr. Dandruff has an altered stratum corneum ultrastructure that is improved with zinc pyrithione shampoo. *J Am Acad Dermatol* 2001; 45: 897–903.
4. Zhai H, Fautz R, Fuchs A, Braonco N, Maibach H I. Assessment of the subclinical irritation of surfactants: a screening open assay model. *Exogenous Dermatol* 2002; 1: 238–241.
5. Tupker R A, Willis C, Berardesca E, Lee C H, Fartsch M, Agner T, Serup J. Guidelines on sodium lauryl sulfate (SLS) exposure tests. A report from the Standardization Group of the European Society of Contact Dermatitis. *Contact Dermatitis* 1997; 37: 53–69.
6. Charbonnier V, Morrison B M Jr, Paye M, Maibach H I. Open application assay in investigation of subclinical irritant dermatitis induced by sodium lauryl sulfate (SLS) in man: advantage of squamometry. *Skin Res Technol* 1998; 4: 244–250.
7. Charbonnier V, Morrison B M Jr, Paye M, Maibach H I. An open assay model to induce subclinical non-erythematous irritation. *Contact Dermatitis* 2000; 42: 207–211.
8. Charbonnier V, Morrison B M Jr, Paye M, Maibach H I. Subclinical, non-erythematous irritation with an open assay model (washing): sodium lauryl sulfate (SLS) versus sodium laureth sulfate (SLES). *Food Chem Toxicol* 2001; 39: 279–286.
9. Wilhelm K P, Surber C, Maibach H I. Quantification of sodium lauryl sulphate dermatitis in man: comparison of four techniques: skin color reflectance, transepidermal water loss, laser Doppler flow measurement and visual scores. *Arch Dermatol Res* 1989; 281: 293–295.
10. Pinnagoda J, Tupker R A, Agner T, Serup J. Guidelines for transepidermal water loss (TEWL) measurement. *Contact Dermatitis* 1990; 22: 164–178.
11. Triebelskorn A, Gloor M. Noninvasive methods for the determination of skin hydration. In: *Noninvasive Methods for the Quantification of Skin Functions*, Frosch P J, Kligman A M, (eds): Basel, Karger, 1993, 42–55.
12. Wilhelm K P, Maibach H I. Skin color reflectance measurement for objective quantification of erythema in human beings. *J Am Acad Dermatol* 1989; 21: 1306–1308.
13. Fullerton A, Fischer T, Lahti A, Wilhelm K P, Takiwaki H, Serup J. Guidelines for measurement of skin colour and erythema. *Contact Dermatitis* 1996; 35: 1–10.
14. Kligman A M. The comparative histopathology of male-pattern baldness and senescent baldness. *Clin Dermatol* 1988; 6: 108–118.
15. Serup J, Winther A, Blichmann C. A simple method for the study of scale pattern and effects of a moisturizer – qualitative and quantitative evaluation by D-Squame tape compared with parameters of epidermal hydration. *Clin Exp Dermatol* 1989; 14: 277–282.
16. Shimizu T, Maibach H I. Squamometry: an evaluation method for a barrier protectant (tannic acid). *Contact Dermatitis* 1999; 40: 189–191.
17. De Paepe K, Janssens K, Hachem J P, Roseeuw D, Rogiers V. Squamometry as a screening method for the evaluation of hydrating products. *Skin Res Technol* 2001; 7: 184–192.
18. Wester R C, Maibach H I. Regional variation in percutaneous absorption. In: *Percutaneous Absorption*, 3rd edition. Bronaugh R L, Maibach H I, (eds): New York, Marcel Dekker, 1999, 107–116.
19. Weltfriend S, Ramon M, Maibach H I. Irritant dermatitis (irritation). In: *Dermatotoxicology*, 6th edition. Zhai H, Maibach H I, (eds): Boca Raton, FL, CRC Press, 2004, 181–228.

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