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Standardized Trauma (Tape Stripping) in Human Vulvar and Forearm Skin

Effects on Transepidermal Water Loss, Capacitance and pH

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Mechanical trauma to genital skin may favor the transmission of sexually transmitted diseases. To study differences between vulvar and forearm skin in epidermal repair after standardized trauma, transepidermal water loss, capacitance and pH of forearm and vulvar skin in 10 healthy premenopausal women were monitored for 7 days after a standardized trauma induced by tape stripping to glistening. Vulvar and forearm skin showed similar responses immediately after tape stripping: a sudden increase in transepidermal water loss and capacitance. Forearm skin, however, reacted more intensely than vulvar skin; forearm skin readings remained significantly higher than normal values for 2 days after tape stripping, whereas vulvar skin readings were not significantly different from normal. Thus, vulvar skin did not respond as extensively as forearm skin, presumably because it is a less complete barrier against excess body water loss. On the other hand, vulvar skin seemed to recover faster from skin damage than forearm skin, probably because of its higher epidermal cell turnover. *Key word: Skin surface pH.*

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The stratum corneum is a major diffusion barrier against excess body water loss and percutaneous penetration of molecules and it protects the organism against physical trauma (1).

Previous studies on the forearm have shown that injury to the stratum corneum by stripping the skin with adhesive tape increases the transepidermal water loss (TEWL) due to the removal of this protective barrier (2–6).

Vulvar skin has been described as a model of specialized skin with the following characteristics:

1. a less complete barrier against water loss,
2. an increased basal cutaneous blood flow and
3. a high 'epidermal cell turnover'.

Since no data are available on the effect of traumatizing the corneal layer of this specialized skin, we studied the effect of this standardized physical trauma on vulvar skin and compared the responses with the reaction of forearm skin in the same individual. Damage to the corneal layers of these two sites were monitored by TEWL, water content and skin surface pH. These results provide information which may help to understand vulvar physiology better.

MATERIAL AND METHODS

Study population

Ten healthy premenopausal women entered the study after signing a written consent form. The study had been approved by the UCSF Committee for Human Research. The women were between 28 and 45 years old.

Tape stripping

Before the stratum corneum of the volar side of the skin of one forearm and the medial part of one labium majus was stripped with adhesive tape (Scotch® Tape 800, 3M), hairs had been clipped off both labia majora. Sites were chosen using a randomization protocol. Skin was stripped until glistening (30–60 times), which indicated near complete removal of the stratum corneum (3).

Measurements

The measurements at the stripped and a symmetrical control site were performed 3 min after tape stripping (day 0), on day 1–4 and day 7. Before all measurements, volunteers had been physically inactive for at least 15 min. The temperature of the test room was 20°C and the relative humidity was 50–60%.

TEWL was measured with an evaporimeter (Servo Med Ep 1, Servo Med, Stockholm, Sweden). The readings expressed in $g/m^2/h$ were converted to values at a standard reference temperature of 30°C (8). Skin temperature was measured with a thermistor (tele thermometer, Yellow

Table I. *Transepidermal water loss (TEWL), capacitance and pH of the forearm and vulvar skin before tape stripping (premenopausal women, n = 10)*

	Vulva	Forearm	*p*-value
TEWL	14.9 ± 3.4	7.4 ± 1.8	< 0.05
Capacitance	87.7 ± 2.5	85.1 ± 2.6	n.s.
pH	5.5 ± 0.5	5.3 ± 0.6	n.s.

Springs Instruments, Yellow Springs, Ohio) on the skin surface.

Capacitance of the skin, as an indicator of stratum corneum water content, was measured with a capacitance meter (corneometer CM 820 PC, Courage and Khazaka, Cologne, West Germany). The corneometer probe was applied to the skin with a slight pressure for 3 s and its values were expressed digitally in arbitrary units.

Skin surface pH was measured with a pH meter (Skin-pH-Meter PH 900 PC, Courage and Khazaka, Cologne, West Germany). The measurements were taken with a glass electrode (Ingold Electrode 403, Electrolyte 9811).

The measured values of TEWL, capacitance and pH were digitized using an AD converter board (Metrabyte DAS 16, Metrabyte, Tauton, Mass.) installed in an IBM AT-compatible computer. The sampling rates for the TEWL were set at one measurement per second over a period of 30 s. TEWL was calculated by taking the average of the values in the final 10 s of the measuring interval.

Statistics

For TEWL and capacitance, values of the stripped site were compared with their symmetrical control and the ratios expressed in percent (relative TEWL, relative capacitance). Since the distribution of these values in this study population does not differ significantly from a normal distribution (Elsner and Maibach, unpublished data), the difference between mean of stripped sites and control sites can be compared, using Student's *t*-test for paired data (9). Skin surface pH of stripped and untreated sites were compared and the differences checked for significance using Student's *t*-test. Statistics were computed on a personal computer (Macintosh SE, Apple Computer Inc., Cupertino, Calif.) with a statistical software package (Stat View 512 +, Brain Power Inc., Calabasas, Calif.).

RESULTS

Table I shows the absolute TEWL values, capacitance and skin surface pH before tape stripping. Vulvar TEWL was significantly higher than forearm TEWL. Capacitance and skin surface pH did not differ significantly between vulvar and forearm skin.

Changes in the relative TEWL over 7 days post stripping are demonstrated in Fig. 1. An immediate significant TEWL increase ($p < 0.01$) was observed

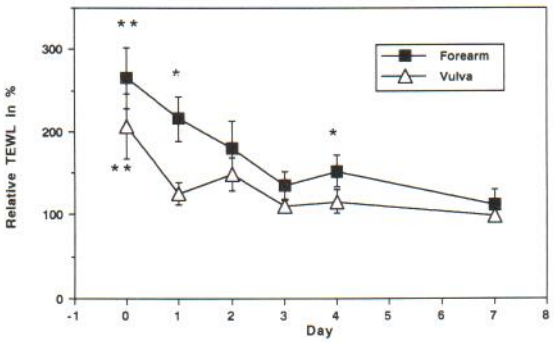

Fig. 1. Relative TEWL (mean ± SE) of vulvar and forearm skin after tape stripping. Significant differences between stripped and control site evaluated by Student's *t*-test for paired data are marked by asterisks $^{*}p < 0.05$, $^{**}p < 0.01$.

3 min after stripping of both vulvar and forearm skin. TEWL on forearm skin remained elevated until the 4th day of study. Vulvar TEWL, however, was only significantly increased immediately after tape stripping. As early as one day post stripping, vulvar TEWL was no longer significantly increased.

Fig. 2 shows increased capacitance 3 min after stripping of vulvar and forearm skin. (Capacitance was significantly increased ($p < 0.05$) and forearm skin ($p < 0.01$)). On vulvar skin, capacitance increased as well, but relative capacitance did not indicate significant differences between treated and untreated sites for any of the subsequent study days. For the forearm skin, relative capacitance values remained low.

Skin surface pH decreased significantly on both forearm and vulvar skin ($p < 0.01$) immediately after the tape stripping, to a minimum of 4.6 ± 0.13

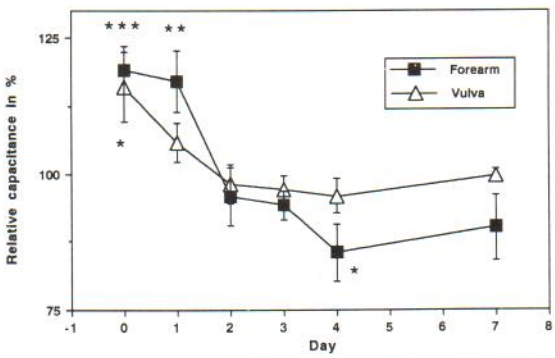

Fig. 2. Relative capacitance (mean ± SE) of vulvar and forearm skin after tape stripping. Significant differences between stripped and control site evaluated by Student's *t*-test for paired data are marked by $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

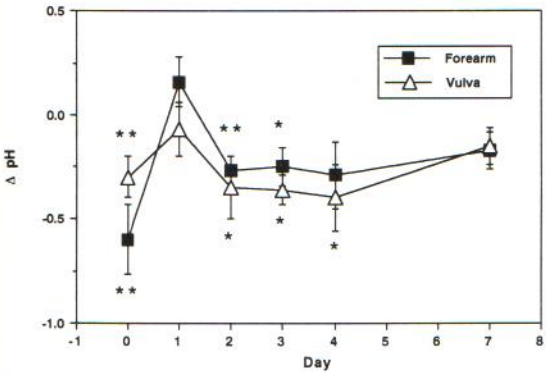

Fig. 3. Differences in the skin surface pH of forearm and vulvar skin after tape stripping. Skin surface pH of the vulvar and forearm decreased immediately after tape stripping (day 0, 3 min after stripping). One day after the trauma, values increased for both anatomical sites and for the remainder of the study skin surface pH readings were decreased. Significant differences between stripped and control site evaluated by Student's *t*-test for paired data are marked by * $p < 0.05$, ** $p < 0.01$.

for the forearm skin and 5.1 ± 0.16 for the vulvar skin. One day post tape stripping (day 1) the skin surface pH increased insignificantly for the forearm skin, whereas skin surface pH of the vulvar skin was almost unchanged. pH decreases were observed during the subsequent days: significant on day 2 ($p < 0.01$) and 3 ($p < 0.05$) for forearm and vulvar skin and still significant for vulvar skin on day 4. Day 7 showed almost unchanged pH values. Fig. 3 demonstrates the differences in pH between the stripped and the control site for vulvar and forearm skin.

DISCUSSION

Vulvar skin has been recognized as a model of specialized skin with increased transepidermal water loss (TEWL), high epidermal cell turnover and increased basal cutaneous blood flow (7). Recently, we have shown that forearm skin reacted more intensively to sodium lauryl sulfate exposure than did vulvar skin (10). After stripping the corneal layers of vulvar and forearm skin, we found a similar phenomenon: forearm skin responses to this trauma were stronger than vulvar skin reactions. Immediately after tape stripping, relative TEWL increased sharply for both sites, but relative TEWL readings of forearm skin were higher than those of vulvar skin. These findings may be explained by the physiologically decreased barrier function of vulvar skin. Further damage to the vulvar barrier results in relatively less TEWL increase than at the forearm.

TEWL increase of forearm skin returned slowly to normal baseline values. Four days after tape stripping, values were still increased. Vulvar skin TEWL, however, was significantly increased only directly post trauma and did not differ significantly from the control site from day 1 till the end of the study. We conclude that vulvar skin recovers more rapidly from this physical trauma than forearm skin does. This may be a result of the physiologically increased epidermal cell turnover of vulvar skin as demonstrated by the dansyl chloride technique, or of the relatively minor damage to barrier function in vulvar skin, since baseline barrier function of vulvar skin is physiologically decreased compared with that of forearm skin (7, 11).

Skin capacitance as an indicator of epidermal hydration increased significantly directly after tape stripping, on both vulvar and forearm skin. This increase was followed by capacitance decreases for the remainder of the study. Tape stripping removes most of the stratum corneum so that capacitance was measured almost directly from the viable epidermis which has a higher capacitance than the stratum corneum.

Two days after tape stripping, capacitance values of stripped skin were lower than at the control site. This reflects a drying effect, especially on forearm skin, which can be explained by a reactive hyperparakeratosis. We observed this dry eczema with decreased capacitance readings on the forearm skin, but vulvar skin seemed to react differently after the trauma. Capacitance values at that site were almost unchanged 1 day post trauma.

The increased TEWL during these study days is another explanation for the drying effect. On the other hand, the lower capacitance values may reflect the beginning of a healing process described by other investigators (12): the inner layers of the epidermis show an increased mitotic activity after tape stripping with the attempt to regenerate the stratum corneum.

On the last study day, capacitance of vulvar skin was back to normal, indicating the regeneration of its corneal layers. Forearm skin capacitance values, however, remained decreased until the last day, showing that regeneration was delayed.

Skin surface pH decreased immediately post stripping. This confirms Szakall's observations dating back to the 1950s (13, 14) that a double pH gradient

exists in the epidermis: Starting from the skin surface, there is one gradient for more acidic values around pH 5.1 in the stratum lucidum and then a second gradient for the pH of the interstitial body fluids of pH 7.4 in the lower epidermis. Szakall attributed the low pH at the inner barrier interface to the specific mixture of amino acids present in this layer. However, his results await confirmation with more refined methods.

Our second finding, that the pH of the stripped area was virtually normal one day after the trauma, may be due to the exsudation of interstitial fluid which is more alkaline. However, on days 2 to 4 when regeneration of the barrier was occurring, pH values of the stripped sites were significantly below control values. This acidification of the skin surface may be a result of the skin's dryness as documented by the capacitance readings. In contrast to TEWL and capacitance, pH dynamics of stripped skin showed no marked differences between the vulva and the forearm. At both sites, pH values had returned to near – normal by day 7. We conclude from our study that mechanical trauma to the vulvar epidermal barrier leads to relatively less change in barrier function than on the forearm, probably since the epidermal barrier is physiologically reduced at the vulva. The post-traumatic regeneration of the epidermal barrier is accelerated at the vulva compared with the forearm. This might be a result of the higher basal epidermal cell turnover of vulvar skin.

The clinical implications of our study relate to a possible control of bacterial and fungal infections of genital skin by improving skin barrier properties. One potential approach would be the topical use of drying agents to reduce the occlusion-related impairment of barrier function. It needs to be explored, however, whether the use of drying agents adversely affects the post-traumatic regeneration of the barrier, which is a desired property of genital skin.

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REFERENCES

1. Mercer EH. Keratin and keratinization. New York: Pergamon Press, 1961.
2. Eriksson G, Lambke LO. Regeneration of human epidermal surface and water barrier function after stripping. Acta Derm Venereol (Stockh) 1971; 51: 169–178.
3. Frödin T, Skogh M. Measurement of transepidermal water loss using an evaporimeter to follow the restitution of the barrier layer of human epidermis after stripping the stratum corneum. Acta Derm Venereol (Stockh) 1984; 64: 537–540.
4. Monash S, Blank S. Location and reformation of the epithelial barrier to water vapor. Arch Dermatol 1958; 78: 710.
5. Spruit D, Malten KE. Epidermal water-barrier formation after stripping of normal skin. J Invest Dermatol 1965; 45: 6–14.
6. Elsner P, Oriba HA, Maibach HI. Physiologie der Haut der Vulva: neue Aspekte. Hautarzt 1989; 40: 411–417.
7. Mathias CG, Wilson DM, Maibach HI. Transepidermal water loss as a function of skin surface temperature. J Invest Dermatol 1981; 77: 219–220.
8. Zar JH: Biostatistical analysis. Englewood Cliffs: Prentice-Hall, 1974; 124–126 and 198–213.
9. Elsner P, Wilhelm D, Maibach HI. Multiple parameter assessment of vulvar irritant dermatitis. Contact Dermatitis 1990; 23: 20–26.
10. Jansen LH, Hojoyo-Tomoko MT, Kligman AM. Improved fluorescence staining technique for estimating turnover of the human stratum corneum. Br J Dermatol 1974; 90: 9–14.
11. Williams MG, Hunter R. Studies on epidermal regeneration by means of stripping method. Arch Dermatol 1957; 114: 384–386.
12. Szakall A. Hautphysiologische Forschung und Gesunderhaltung der Haut. Fette und Seifen 1951; 53: 399–405.
13. Szakall A. Über die Eigenschaften, Herkunft und physiologischen Funktionen der die H-Ionenkonzentration bestimmenden Wirkstoffe in der verhornten Epidermis. Arch Klin Exp Dermatol 1955; 201: 331–360.