

Transepidermal water loss in adhesive tape induced dermatitis

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As an index of skin barrier function, transepidermal water loss (TEW) was investigated in subjects reactive to adhesive tapes. Tape reactive subjects showed no difference in TEW in untreated skin when compared to non-reactive subjects. Plastic tape and transparent tape produced varying degrees of dermatitis in reactive subjects; the TEW was increased up to 40-fold of the baseline values correlating with the degree of dermatitis. Paper tape and plastic film without adhesive did not produce dermatitis and increased water loss. Regeneration of skin damage was accompanied by a decrease of TEW values. The general problem of tape reactors and tape irritation is discussed.

Key words: skin barrier function – tape dermatitis – transepidermal water loss.

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Adhesive tape dermatitis has several possible etiologic components: irritant and allergic contact dermatitis, miliaria, bacterial and fungal folliculitis, and mechanical traction. Porous paper tapes represent the single most important technical innovation in decreasing tape dermatitis; presumably their transmissibility of water vapor plays some role in their decreased irritancy. The present study compares water vapor loss in the skin of tape reactors to non-tape reactors in an attempt to characterize the skin properties of the tape reactor.

Methods and Materials

Transepidermal water loss (TEW) was measured by the techniques of Thiele & Malten (1972), Spruit & Malten (1966) and Thiele et al. (1972) with the Meeco electrolytic water analyser model W using dry nitrogen as carrier gas. Nitrogen was passed through Silica-gel and Teflon tubes to a 1.8 cm²

cylindrical capsule placed upon the skin with Velcro® bindings. Gas flow was kept at 100 cc/min. Water vapor values exceeding 1000 ppm were determined by opening a bypass. Measurements were started after a stable baseline of less than 10 ppm was obtained; readings were taken when the indicator remained stationary for five minutes showing that a steady state had been reached.

The tests were performed on the volar aspect of the forearm after a preconditioning period of limited physical activity for one hour in a temperature-controlled room (21–22°C; 40–45 % RH). Skin temperatures were measured with a tele-thermometer (Yellow Springs Instruments, Antioch, Ohio). The probes were attached to the skin with paper adhesive tape in an attempt to obtain even pressure. Values obtained for TEW were normalized to a temperature of 32°C by the method of Thiele & Malten (1972).

Occlusion without an adhesive mass was obtained by an 8 × 8 cm square of plastic film (Saran Wrap®) attached to the skin by 1.3 cm wide occlusive tape (Blenderm®).

The tapes employed were:

1. A microporous non-woven rayon backing tape with an acrylic copolymer adhesive ("paper tape"): 3 × 2.5 cm pieces.
2. A transparent, polyvinyl chloride backing, perforated tape with a rubber resin adhesive ("transparent tape"): 8 × 5 cm pieces.
3. A non-porous occlusive polyvinyl chloride backing with a rubber-based adhesive ("plastic tape"): 8 × 4 cm pieces.

Appropriate test subjects were obtained by applying for 72 hours the above noted commercially available adhesive tapes to the back of Caucasian male volunteers above 21 years. Those developing tape dermatitis on their back within 72 hours were studied further. Some subjects reacting on their back did not react on the forearm and were not further tested. The control non-tape reacting subjects were of the same sex and of approximately the same height, weight and age distribution and living under similar conditions. Subjects with a history of rubber dermatitis or who developed lesions suggesting folliculitis or miliaria were excluded. All measurements were performed in the morning. Subjects were from a population that did not perform extensive physical activities. Subjects were studied in autumn and winter.

The tapes were applied without special pretreatment to the volar aspect of the forearm in the following order from the cubital fossa to the wrist:

Right arm: transparent tape, paper tape, plastic tape.

Left arm: plastic occlusion.

The tapes remained in place for 72 hours. TEW measurements were taken 1–2 hours after tape removal and were repeated at intervals thereafter (approximately at 3, 6,

8 and 10 days). TEW of untreated normal skin (as a control) was measured in each individual on the left forearm 8 cm above the wrist. Persons with no history of hyper-reactivity to tape were examined for comparison; only those not demonstrating tape dermatitis were included in this control group.

The degree of tape reaction was estimated from the lesion morphology and divided into three groups:

Mild: erythema only, grade 1–3.

Moderate: erythema, grade 4–9 and infiltration.

Severe: erythema, infiltration and micro-vesicles or gross exudation.

The erythema grading scale was 11 points:

0 – no erythema.

1 – erythema not covering the test site.

3 – mild confluent erythema.

5 – moderate confluent erythema.

7 – moderately severe.

10 – very severe erythema.

The data was analyzed with Student "t" test, and the Wilcoxin Test.

Results

Non-tape reactors. In initial experiments transepidermal water loss (TEW) was studied in six control subjects (non-tape reactors) over several days (Table 1). The mean value on day 1 was 0.52 ± 0.02 mg of water/cm²/h. Occlusion (without adhesive), paper tape, transparent tape and plastic tape had no significant effect on TEW when compared to sites without tape either immediately after tape removal or 3 or 10 days later. In the case of plastic tape, slightly higher values were obtained. The decrease was statistically not significant when compared to the test site without tape. The application of these tapes or occlusion to the skin of non-tape reactive subjects did in no case produce visible skin changes.

Table 1. Transepidermal water loss measurements in non-tape reactive subjects (Control group)

Treatment	# 1	Day # 3	# 10
		mg H ₂ O/cm ² /h	
Untreated skin (control)	.52 ± .02 (6)*	.49 ± .02 (5)	.48 ± .07 (6)
Occlusion only (plastic film)	.57 ± .1 (5)	.52 ± .11 (5)	.54 ± .11 (5)
Paper tape	.50 ± .03 (6)	.50 ± .05 (5)	.50 ± .08 (6)
Plastic tape	.75 ± .11 (6)**	.62 ± .1 (5)**	.62 ± .12 (6)**
Transparent tape	.54 ± .06 (6)	.51 ± .07 (5)	.48 ± .08 (6)

* $\bar{X} \pm \text{S.E.M. (N)}$

** No significant difference from other test sites

Tape reactors. We examined tape reactive subjects with various tapes.

No difference was found in the baseline TEW in untreated skin of the control group (non-tape reactors) and the tape reactive group (0.52 ± 0.02 and 0.54 ± 0.04 mg of water/cm²/h, respectively). This suggests that baseline water permeability of the skin *per se* does not account for the proclivity to tape dermatitis.

This data is divided into two parts: their response to treatments not producing dermatitis and to that producing dermatitis. In sites without dermatitis (Table 2a), there was no significant increase above baseline values in TEW at days 1, 3 or 10 after occlusion without adhesive or paper tape.

After treatment with plastic or transparent tape, dermatitis of varying degree and a marked increase in TEW was observed (Fig. 1). The increase in TEW cor-

related rather well with the severity of the dermatitis (Table 2b). Thus, in sites with a mild dermatitis there was on the average an increase of approximately 50 % in TEW compared to the untreated skin; with moderate dermatitis, the TEW increased to greater than two-fold and greater than 14-fold in severe dermatitis.

The repair of the damaged skin was studied by following the TEW of the dermatitic site serially (Fig. 2). For the entire group, TEW was as great or greater by the third day than shortly after tape removal (day 1); by 6-10 days, TEW approached but did not reach normal baseline levels. This refers to the response of the entire group. However, this response to skin damage was not found in all subjects studied. In some cases TEW increased from day 1 to day 3 (Fig. 3a), whereas, in other subjects TEW was already decreased by day 3 (Fig. 3b). The

Table 2a. TEW - In non-dermatitic sites in tape reactive subjects

Treatment	# 1	Day # 3	# 6-10
		mg H ₂ O/cm ² /h	
Untreated skin (control)	.54 ± .04 (21)*	.54 ± .04 (11)	.48 ± .06 (10)
Paper tape	.48 ± .04 (19)	.49 ± .06 (10)	.48 ± .06 (11)
Occlusion (plastic film)	.63 ± .06 (11)	.50 ± .07 (9)	.43 ± .06 (3)

* $\bar{X} \pm \text{S.E.M. (N)}$

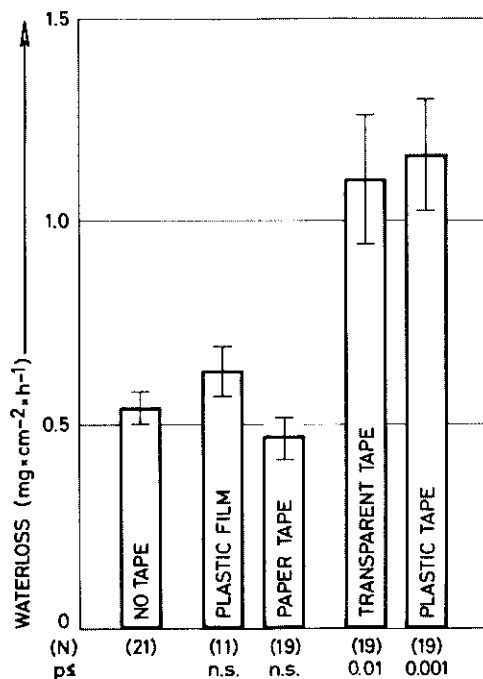


Fig. 1. Effect of tapes on TEW in tape reactors on day of tape removal. Note that the transparent tape and plastic tape treated sites showed greatly increased TEW values. The number of subjects studied is in parenthesis. The S.E.M. and the p values are indicated. n.s. = not significant.

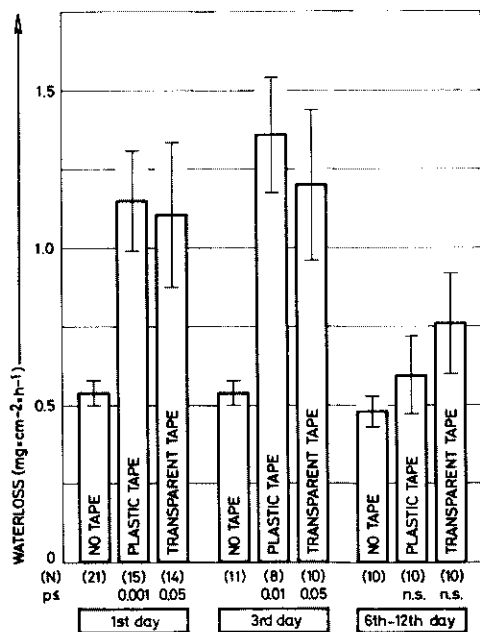


Fig. 2. Regeneration of the water barrier after tape dermatitis from the day of removal to 3 and 6-12 days later. All subjects were studied throughout. Note that the average values at day 3 were similar to day 1. Individual exceptions are discussed in the text. The number of subjects studied is in parenthesis and p values shown. n.s. = not significant.

type of response could not be correlated with the type of tape used or with the degree of dermatitis observed initially.

The correlation between the increase in TEW with one tape that produced dermatitis compared to the other is shown in Fig.

Table 2b. TEW - In dermatitic sites in tape reactive subjects (on day of tape removal)

Treatment	Degree of clinical reaction		
	Mild	Moderate mg H ₂ O/cm ² /h	Severe
Plastic tape	.88 ± .09 (10)* p ≤ 0.001 ¹	1.63 ± .31 (6) p ≤ 0.05 ¹	9.95 ± 4.95 (4) p ≤ 0.01 ²
Transparent tape	.74 ± .12 (7) p ≤ 0.05 ¹	1.38 ± .32 (6) p ≤ 0.05 ¹	7.5 ± 3.56 (5) p ≤ 0.01 ²

* $\bar{X} \pm \text{S.E.M. (N)}$

¹ Compared to values of untreated skin (.54 ± .04(21) mg H₂O/cm²/h) with Student "t" test.

² Compared to values of untreated skin and mild dermatitic test sites with Wilcoxon test.

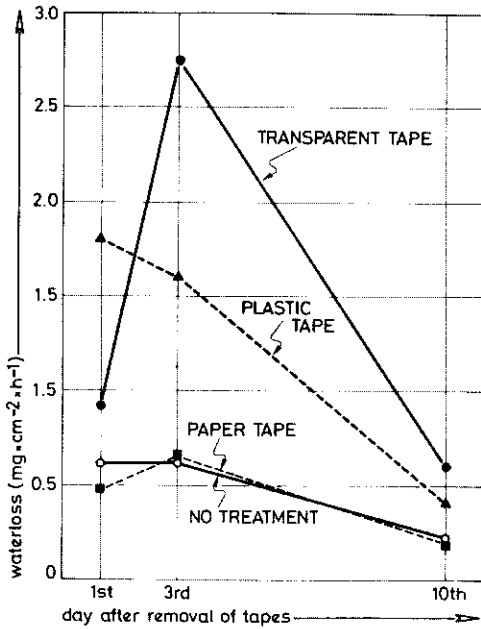


Fig. 3a. TEW after 3 and 10 days in one subject. Note that the transparent tape values increased by day 3; the plastic tape values did not.

4. Including all data there was a positive correlation between TEW produced with both tapes ($r = 0.972$). By removing the two subjects with the highest TEW values the correlation was greatly decreased ($r = 0.405$).

Discussion

Transepidermal water loss (TEW) is a measurement of the water barrier function of skin and an index for the degree of skin damage. It has been studied *in vivo* in physical damage due to stripping (Spruit & Malten 1965, 1966; Baker & Kligman 1967; Matoltsy et al. 1962) and burns (Fallan & Moyer 1963), chemical damage from alkali and other chemicals (Malten & Spruit 1966; Baker & Kligman 1967; Raffle & Shahidullah 1970) and in different forms of hyperkeratoses and dermatitis (Baker & Kligman

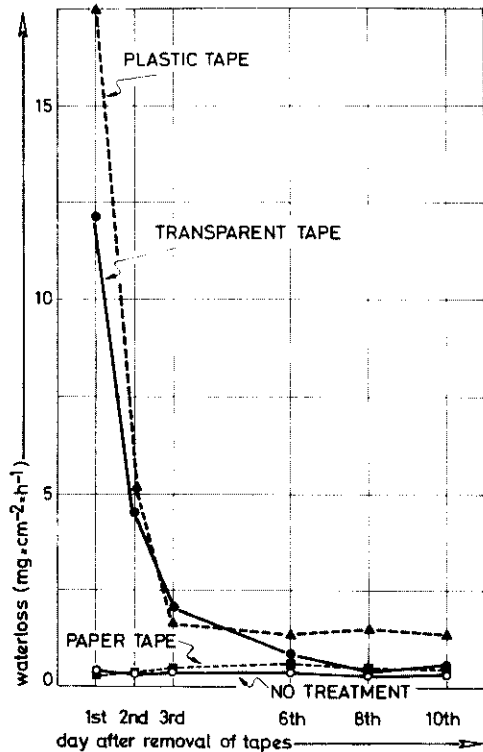


Fig. 3b. TEW after severe dermatitis. Note asymptotic curve: return to normal was not complete at 10 days. The scale is different from Fig. 3a.

1967, Shahidullah et al. 1967, 1969; Spruit & Malten 1965; Felsher & Rothman 1945).

There are no prior studies on the relationship of TEW in tape reactions with which to compare the present data.

Since no agreement exists on the normal value of TEW in untreated skin of the volar aspect of the forearm, we studied TEW in several normal subjects on different days (Table 1). The mean values are similar to those published utilizing similar methods and test sites as we did (Thiele & Malten 1972; Thiele et al. 1972; Baker & Kligman 1967; Shahidullah et al. 1967, 1969). The actual values might have been slightly lower if measured closer to the antecubital fossa instead of 8 cm above the wrist, since

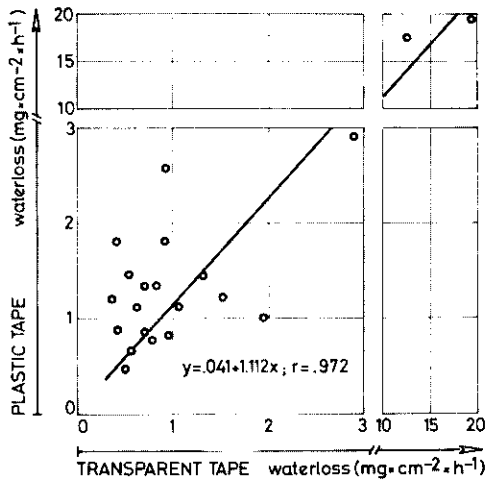


Fig. 4. Correlation between water loss after application of plastic tape and water loss after application of transparent tape.

Thiele & Malten (1972) reported that TEW increases from the cubital fossa to the wrist.

Thiele & Malten (1972) described greater variations of these values from subject to subject and from day to day. In this study, minimal daily or intersubject variations were observed. We have no definitive explanation but wonder if this is due to the regulated living conditions of our volunteers and our larger test panel.

The mean values in untreated sites of tape reactors were similar to the non-reactors with minimal intersubject and daily variations. This suggests that skin permeability to water does not *per se* explain the proclivity or resistance to irritant tape dermatitis.

Application of these adhesive tapes to non-tape reactive subjects neither changed the skin appearance nor altered the TEW, regardless if measured immediately after tape removal or several days later. This would indicate that the skin barrier function for water is not altered by the tapes *per se*, but may be correlated with the skin damage induced by tape.

This is further supported by the results obtained with the tape reactor group. In this group, the plastic and transparent tapes produced an increasing TEW and a dermatitic reaction of varying degree, while the paper tape did not alter the skin visibly and the TEW remained unchanged.

In the tape reactor groups, the plastic and transparent tapes produced an increased TEW and a dermatitic reaction of varying degree, while the paper tape did not alter the skin visibly and the TEW remained unchanged. The possibility that the increased TEW after application of plastic and transparent tapes was an effect of the occlusive backing of the tapes is unlikely, as the test sites treated with plastic film occlusion (without adhesive) did not show an increase of TEW. Although in two cases transient erythema after occlusion occurred, no altered TEW was observed.

However, the correlation between the degree of dermatitis produced by these two tapes and the amount of water vapor loss suggests that the dermatitis may be responsible for the increased TEW.

In another model of skin damage – serial cellophane tape stripping – a relationship between the number of layers removed and the increase of TEW was observed (Thiele et al. 1972; Baker & Kligman 1967; Raffle & Shahidullah 1970; Matoltsy et al. 1962; Spruit & Malten 1965). In the latter studies TEW increased gradually in the initial strippings; in later strippings a sharp increase of the TEW up to 50-fold occurred. This observation may explain the large variation seen in our group with severe dermatitis in which a 30–40-fold increase was measured, compared to only a 3–6-fold increase in the other severe and moderate cases.

This data supports the concept that TEW depends on the degree of dermatitis, but does not explain why different degrees of reactions were observed under the same

treatment. Regardless of the degree of the dermatitis, TEW decreased to values close to normal within 6–12 days after tape removal. At 6–12 days it appeared that at the dermatitic site TEW values were somewhat greater than baseline. At that late stage there were no statistical differences. A similar gradual return to normal between two weeks and one month has been observed after different types of skin damage (Spruit & Malten 1966; Baker & Kligman 1967; Raffle & Shahidullah 1970). In our studies the dermatitis was still resolving with slight scaliness and sometimes mild erythema even at day 10–12.

On the third day after tape removal the average value for TEW is similar to day 1. In individual cases it can be higher than on the first day with concordant or more severe dermatitis or it can be considerably lower than on the first day with clinical improvement of the dermatitic reaction.

The different behavior in different subjects in the beginning of the regeneration phase requires explanation. It was observed in some dermatitis cases by Shahidullah et al. (1969) and may relate to the individual inflammatory response to the irritant agent. It is possible that this normal healing response is related to the individual's ability to harden to irritants. A complete understanding of these variable responses should develop insight into the problem of the patient who does not heal as expected.

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