TRANSEPIDERMAL WATER LOSS OF HUMAN NEWBORNS*

RICHARD H. WILDNAUER, PH.D. AND ROBERT KENNEDY

ABSTRACT

Transepidermal water loss (TWL) measurements of healthy human term newborns were determined by resistance hygrometry. The average TWL of newborn upper back skin was found to be slightly but significantly lower than the TWL of comparable adult back skin. These data suggest that some morphological or physiological differences exist between newborn and adult epidermis which influence TWL. The observation of a lowered TWL can be interpreted either as a more efficient physical barrier in the newborn or, alternatively, as the result of the influence of eccrine activity on TWL. No statistical significance between weight, age or sex of the newborn and the observed TWL was present in this study.

Although there have accrued in the literature extensive data concerning transepidermal water loss (TWL) of normal adult epidermis (1-5), there are no comparable data available for restricted areas of human newborn epidermis. Related measurements of newborn total body insensible water loss made in conjunction with thermoregulation and incubator development have indicated that newborn basal values differ from the adult (6-8). Little et al. (6) and Levine et al. (7) have reported that the evaporatory water loss per unit area of total skin surface during the first few weeks after birth is between 33 and 50% lower than that found for adults. These measurements, more appropriately called total evaporatory water loss, are an average of the water evaporated from the whole body surface minus respiratory water vapor contributions. These basal values were obtained at ambient temperatures below the threshold of thermoregulatory sweating. These data, however, are unable to give information concerning water vapor contributions from an accurately determined localized area of the epidermis as given by TWL.

Newborn TWL data therefore were of interest to determine whether or not any differences exist between the physiological functions of newborn and adult epidermis as reflected by TWL.

MATERIAL AND METHODS

Measurements. TWL was measured using the technique and equipment described in a previous publication (1). Briefly, TWL measurements were performed with a Sage electric hygrometer, Model 154, using lithium bromide sensing elements (Hygrodynamics, Inc., Silver Springs, Md.). Dry air is passed over the skin surface via a sampling chamber subtending a 16 cm² area of skin (A). The relative humidity (RH) and temperature (T) of the air is monitored prior to and following its passage over the exposed skin surface, with the difference in relative humidity (ΔRH) representing the water vapor picked up at the skin surface. Volumetric air flow rates (AF) were maintained constant by a Matheson 602 flow meter.

Calculation of TWL was made according to the formula:

\[ TWL = \frac{\Delta RH}{100} \times D \times AF \times \frac{1}{A} \]

Where:
- TWL is the transepidermal water loss in mg cm⁻² hr⁻¹
- ΔRH is the difference between the incoming and effluent relative humidities
- D is the weight of water per liter of saturated steam at the temperature of the air passing over the skin in mg l⁻¹
- AF is the volumetric air flow rate in 1 hr⁻¹
- A is the area of skin in cm²
- the density of saturated steam (D) at different temperatures was obtained from tables (9).

Approximately 15 minutes prior to measurement each newborn subject was placed on its stomach in a small cradle with the upper back and rump exposed. The 4 cm x 4 cm sampling chamber was held in place on the upper back by an assisting nurse. Measurements were made only on resting subjects. The ambient temperature in the environmental chamber where TWL measurements were made was maintained between 72° and 78° F.

The adult subjects used for TWL measurements were allowed to rest in a prone position prior to and during measurement. The ambient tempera-
ture for adult TWL measurement was maintained between 70° and 74° F.

The RH of the effluent air in all measurements was maintained at approximately 3% to establish a constant opposing water vapor pressure within the sampling chamber. This was accomplished by appropriate adjustment of volumetric air flow rates between 150 and 300 ml/min. The RH of the dry air entering the sampling chamber was generally 1.5%. Effluent RH readings were not recorded until the hygrometric system and skin surface had equilibrated as evidenced by a constant RH reading for five minutes. Each measurement required approximately 15 to 20 minutes.

In our experience, excessive emotional sweating appears as transient rapid increases in water loss which are easily distinguished from baseline TWL. Similarly, thermoregulatory stimulation appears as rapid and large increases which do not rapidly return to baseline TWL.

Subjects. The 39 newborn subjects were of both sexes (12 male, 27 female) ranging in ages from 12 to 234 hours and weights from 2.7 to 4.5 kg. The subjects were healthy term newborns of both private and clinic cases from Rhode Island and Massachusetts residents. Adult subjects were healthy laboratory personnel.

RESULTS

The results are summarized in the tables. The mean TWL for human newborn upper back skin was found to be 0.18 ± 0.06 mg/cm²/hr as compared with 0.27 ± 0.04 mg/cm²/hr for the adult. Newborn TWL values ranged from 0.11 to 0.33 mg/cm²/hr with an average variation of 8% between duplicate readings on the same subject. The mean TWL was found to be significantly lower in the newborn as compared with the adult (p = 0.05). No positive correlation between weight, age or sex (male = 0.17 ± 0.05 mg/cm²/hr, female = 0.18 ± 0.06 mg/cm²/hr) of the newborn and observed TWL were present in the ranges studied. The observed 30% lower TWL present in the newborn corroborates the 33 to 50% decrease observed in total evaporatory water loss by Little et al. (6) and Levine et al. (7).

TABLE I

<table>
<thead>
<tr>
<th>Area</th>
<th>TWL (mg/cm²/hr) Mean ± S.D.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Upper back</td>
<td>0.18 ± 0.06</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Rump</td>
<td>0.17 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Upper back</td>
<td>0.27 ± 0.04</td>
<td></td>
</tr>
</tbody>
</table>

* The mean for newborn back skin is significantly less than the mean for the adult (P = 0.05).

TABLE II

<table>
<thead>
<tr>
<th>Range (hrs)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-40</td>
<td>8</td>
</tr>
<tr>
<td>41-70</td>
<td>18</td>
</tr>
<tr>
<td>71-100</td>
<td>18</td>
</tr>
<tr>
<td>101-234</td>
<td>5</td>
</tr>
</tbody>
</table>

Mean age = 67 hrs.

The TWL value of 0.27 mg/cm²/hr for normal adult upper back skin reported here is in good agreement with the 0.29 mg/cm²/hr reported for adult back skin by Baker and Kligman (2) using similar conditions and technique.

COMMENT

It is generally accepted that TWL is a process in which water vapor passively diffuses through the avascular stratum corneum from the highly hydrated underlying tissues (10). This biologically inert membrane due to its dense, fibrous, lipoprotein matrix represents the principle physical barrier to the penetration of molecules through the integument. Therefore, the magnitude of TWL has been widely used as a measure of the effectiveness of this barrier in dermatological disease states (1, 5) as well as a kinetic measure of barrier replacement (11).

Close analysis of the extensive literature data indicates that absolute values of TWL largely depend on the technique and experimental conditions used in its measurement. However, it is evident that with any given technique the values of TWL consistently vary topographically from skin site to skin site (2, 3, 5). Stratum corneum thickness differences have been unsuccessful in accounting for all the observed TWL variations. The relative contributions of chemical composition, membrane structure, and immediate physiological influence on the membrane in accounting for these topographical TWL variations are not completely resolved.

There are a number of factors which might be responsible for the observed 30% lower TWL in the human newborn during the first few postnataal weeks. Since it has been demonstrated that the penetration rate of molecules through stratum corneum can be approximated by Fick's law (12), a thickened corneum in the newborn could account for the decreased TWL. A thickened membrane is not physiologically unreasonable since
in utero the epidermis is in a state of high metabolic activity in combination with minimal surface abrasive forces to affect the desquamation rate of stratum corneum cells prior to birth. Histological observations by Vinson et al. (13) have indicated that human newborn back epidermis is extremely dense, with parakeratotic layers and prominent corneum indicative of very active growth and hyperkeratinization. Therefore it might be suggested that enhanced barrier properties of the newborn stratum corneum cells which desquamate during the first several post natal weeks are a result of something unique to their in utero formation. There are however no convincing in vitro permeability data to support these factors as being responsible for the decreased newborn TWL.

A second factor which can influence TWL is the skin surface temperature. It has been demonstrated that like all membrane diffusion processes TWL has a characteristic activation energy and therefore its magnitude is temperature dependent (14-16). Grice et al. (14) reported that a 5°C fall in the skin temperature of two subjects lowered the TWL between 38 and 53%. Skin surface temperatures were not monitored during the newborn TWL measurements; however, it is unlikely that lower newborn skin temperatures are responsible for the lowered TWL in light of the findings of Kurata et al. (17) that newborn trunk skin temperatures tend to be higher than for adults.

However, the most significant factor suggested by this work poses questions concerning the actual physiological mechanism of TWL, a process at present poorly understood. Substantial evidence is accruing (15, 18) which suggests that the phenomena of TWL is not simply a physical process following physicochemical laws but that some physiological processes can participate in the mechanism and therefore influence the magnitude of TWL. Mole (19) was the first to give recognition to the existence of such a variable under direct physiological control in his concept of “skin relative humidity” but gave no indication concerning the control mechanism. More recently other workers (20-22) have presented evidence which strongly suggests that this physiological involvement may be the neural control of the eccrine sweat gland.

The resultant of this interaction of eccrine gland activity with stratum corneum properties which influences TWL can be interpreted as a hydration effect on membrane permeability. Permeability studies with inert membranes in which substantial amounts of the penetrant dissolves indicate that there is a departure from ideal membrane behavior and hence the diffusion constant and permeability rate are not independent of solute concentration within the membrane (23). Stratum corneum has a strong affinity for water and therefore permeability of water through it depends on the hydration level of the membrane (4, 24, 25). However, in vivo evaluation of stratum corneum surface hydration and the concentration gradient across the membrane are presently experimentally unattainable. Adams (21) has, however, given indirect evidence for altered stratum corneum hydration measured as a change in skin surface friction following electrical stimulation of the eccrine glands in the foot pad of the cat.

One might therefore postulate that TWL is under immediate physiological influence manifested through minimal eccrine gland activity with lateral diffusion of the water into the periductal area of the stratum corneum. Skin biopotential measurements have indicated that neural stimulation of eccrine glands occurs even under conditions where there is no thermoregulatory stimulation (26). Due to the concentration dependence of the permeability of water through stratum corneum (4, 24, 25) this supplemental hydration mechanism would be expected to cause an increase in TWL. The lag time between neural stimulation and an increase in the steady state flux (TWL) would depend on the hydration level of the stratum corneum prior to stimulation and the diffusion rate of water through the stratum corneum to the surface. The cooling of the eccrine duct in the stratum corneum most pronounced in the thickened corneum of the palms and soles serves to maximize the surface area contact between the source of water and surrounding stratum corneum cells and hence is a highly efficient physical mechanism for lateral diffusion.

In view of substantial evidence supporting this concept of a direct physiological influence on TWL coupled with the fact that the human newborn has an immature neural control of eccrine gland activity (27, 28) it is tempting to speculate that the disparity in basal eccrine activity between the adult and newborn is principally responsible for the observed decrease in TWL. Kuno (29) and others (28) have indicated that during the first several postnatal weeks human
newborns are unable to sweat or sweat very inefficiently in response to thermal stimulation. Complete neural control of eccrine activity by the infant has been reported to be attained by 2 or 3 years of age.

Similarly, it has been found that TWL of most geriatric skin areas is lower than that present in normal adult epidermis (30, 31). Since geriatric subjects also have decreased neural control of eccrine glands (32), the latter observation is consistent with the newborn TWL data and gives further support to the proposal that TWL is influenced by eccrine activity.

The good agreement between lower TWL present in newborn upper back skin as well as rump skin and the lower newborn total evaporative water loss strongly suggests that the physiological mechanism responsible for the lower TWL applies to most skin areas. However, the exact causative factor or factors responsible await a more complete understanding of physiological inter-relationships between stratum corneum hydration, the contribution of minimal eccrine activity and their influence on the magnitude of TWL.

REFERENCES


The newborn subjects reported herein were made available through the courtesy of Professor Lewis P. Litsitt, Ph.D., of Brown University, in his Sensory Assessment and Conditioning Laboratory at Providence Lying in Hospital, supported by USPH Grant NB-04268.