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IN VIVO TRANSEPIDERMAL WATER LOSS AND EPIDERMAL OCCLUSIVE HYDRATION IN NEWBORN INFANTS: ANATOMICAL REGION VARIATION

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Abstract. Transepidermal water loss (TEWL) was measured from the abdomen, buttock, and central forearm in 13 term infants by employing an electrolytic water analyzer (Meeco). The hydration level (HL) at these sites following one hour of occlusion and the resulting post-occlusion TEWL were measured. No apparent difference in TEWL was found between regional sites. The forearm and buttock HL appeared similar, while the abdomen values tended to differ considerably from both. Post-occlusion TEWL appeared significantly higher than normal TEWL. Since the buttock and forearm TEWL reflected similarly structured stratum corneum, future studies on the more accessible forearm may be extended by application to the buttock.

Key words: Skin, Transepidermal water loss; Newborns

The stratum corneum is a primary barrier against the physical and biological environment; transepidermal water loss (TEWL) is one parameter which reflects its integrity by Monash & Blank (5), Kligman (4), Vinson et al. (10), Spruit & Malten (9) and Eriksson & Lambe (2). In infants, Rutter (6) demonstrated that TEWL was high and variable in the first 4 hours after birth, settling to a constant level thereafter. Cunico et al. (1), measuring older newborn infants and adult TEWL with an electrolytic water analyzer (Meeco), observed that newborn term infants have less TEWL than adults, possibly indicating a more efficient stratum corneum. Hammarlund et al. (3), using an evaporimeter (ServoMed), graphically compared measurements in 18 newborn infant skin sites, concluding that total TEWL can be estimated by measuring small test areas.

The present study involves (*a*) measuring TEWL from three distinct anatomical regions: abdomen, buttock, and ventral forearm in newborn term infants by employing the electrolytic water analyzer (Meeco) and comparing these values with the evaporimeter measurements of Hammarlund et al. (3), and (*b*) measuring and comparing the hydration level (HL) at these sites following one hour of occlusion (and the resulting post-occlusion TEWL). The buttock is of particular interest as it is often occluded by a diaper.

MATERIALS AND METHODS

Thirteen newborn term infants, 39-41 weeks gestational age, were studied following parental consent in the Well-Baby Nursery at the University of California Medical Center. TEWL measurements were taken 8–24 hours post partum except for 2 subjects measured between 24 and 48 hours. All infants were healthy, average for gestational age, and were measured in open cribs at a room temperature between 23.5 and 25.0°C. Blankets and diapers were partially removed during measurement. 1.5 cm² of occlusive plastic film (Parafilm) backed by plastic tape (Blenderm, MMM, St. Paul, MINN) were placed, one each, on the abdomen, buttock, and forearm of the infant and removed after one hour.

Measurements followed those of Cunico et al. (7): TEWL and HL measurements were taken with an electrolytic water analyzer (Meeco, Warrington, PA) coupled with a chart recorder (OmniScribe, Houston, TX). Dry nitrogen gas, 99.9% purity, was passed through the sample cup at 100 cc min^{-1} (50 cc min^{-1} for HL measurement). The parts per million (ppm) water loss values obtained with the analyzer were converted to μg cm^{-2} h^{-1} with the equation:

$$TEWL_{\mu g\ cm^{-2} h^{-1}} = TEWL_{ppm} \frac{(0.0736\ \mu g\ min^{-1})\ (60\ min)}{0.6\ cm^2}$$

where: $TEWL_{ppm}$ = water loss in ppm, 0.0736 μg min^{-1} = factor converting 1 ppm H_2O per 100 cc to μg H_2O per 100 cc at 25°C and 760 mmHg, and 60 min = hour. (Since temperature and pressure corrections produced insignificant changes in TEWL, they were discarded.)

Upon removal of the occlusion patch, the experimenter separated the sample cup from its Parafilm cover (sample air previously dried to a basal level) and slid it onto the site, thus minimizing atmospheric contamination. HL and post-occlusion TEWL were then measured. Hydration level (HL) refers to the amount of free water in the stratum corneum removable in seconds to minutes; the hydration level measurement drops in time to a steady level equivalent to TEWL (Fig. 1). HL was determined by

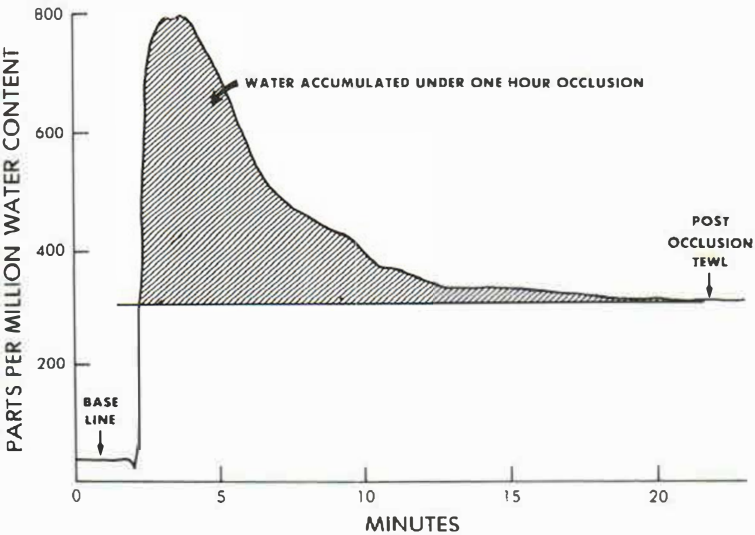

Fig. 1. Hydration level curve. The hydration refers to the amount of free water in the stratum corneum. Note its rapid removal with dry nitrogen (see text for details).

measuring the area under the ppm curve traced by the analyzer from the time the sample cup reached the occluded site (patch removed) until the ppm trace stabilized to a resting rate (Fig. 1). The curve was cut out, weighed with a four decimal place balance and compared with the weight of a rectangle of chart paper 100 ppm high by one minute wide. The weight of water represented by this rectangle was calculated at 3.68 μg using a nitrogen flow rate of 50 cc min^{-1}.

Total hydration ($\mu g\, cm^{-2}$) was calculated as follows:

$$\text{Total hydration}_{\mu g\, cm^{-2}} = \frac{\dfrac{\text{wt. of curve, g}}{\text{wt. of rectangle, g}}\ (3.68\ \mu g)}{0.6\ cm^2}$$

where: 3.68 μg=amount of water represented in the 100 ppm rectangle, and 0.6 cm^2 = area of skin sampled.

RESULTS

Mean, standard deviation (S.D.), and standard errors of the mean (S.E.) for normal skin are given for each site (Table I). A randomized block analysis of variance was performed; since the calculated F =1.50 is less than 3.4 (that associated with P =0.05 for 2 and 23 degrees of freedom (d.f.), sites and error mean square, respectively), there is no apparent significant difference between TEWL from these normal skin sites.

An F was calculated for "individuals"=5.62. Since this is larger than 2.2 (that associated with P =0.05 for 12 and 23 d.f., individuals and error mean square, respectively), a significant difference presumably exists between infants.

The TEWL from sites occluded for one hour are presented in Table II; a randomized block analysis of variance was performed. Since the calculated F=1.59 is less than 3.50 (that associated with P =0.05 for 2 and 20 DF, sites and error mean square, respectively), there is no apparent difference between skin sites.

An F calculated for individual difference=13.81 which is greater than 2.60 (that associated with P = 0.05 for 10 and 20 DF, individuals and error mean square, respectively). A significant difference between individual infant TEWL is apparent.

Table I. *Normal transepidermal water loss ($\mu g\ cm^{-2} h^{-1}$) non-occluded sites*

Infants	Abdomen	Buttock	Forearm
1	439	460	460
2	425	474	340
3	510	552	531
4	814	672	1 097
5	410	283	658
6	587	425	580
7	559	872	715
8	313	365	345
9	431	444	496[a]
10	403	411	453
11	743	672	580
12	481	587	637
13	524	793	687
Mean	510.7	539.2	583.0
S.D.	±139.9	±172.7	±195.6
S.E.	±38.8	±47.9	±54.2

[a] Estimated datum necessary for statistical manipulation, calculated according to Woolf (9).

Table II. *Transepidermal water loss ($\mu g\ cm^{-2}\ h^{-1}$) after one hour of occlusion*

Infants	Abdomen	Buttock	Forearm
1	1 062	1 415	1 294
2	495	566	602
3	849	495	566
4	1 239	1 451	1 355[a]
5	623	906	871
6	849	651	779
7	1 211	950	1 205
8	796	835	757
9	–	–	–
10	637	991	637
11	828	970	955
12	835	1 401	1 118
13	–	–	–
Mean	815.8	966.5	921.7
S.D.	±361.3	±336.0	±283.9
S.E.	±108.9	±101.3	±85.6

[a] Estimated datum necessary for statistical manipulation, calculated according to Woolf (9).

The TEWL from normal sites were compared with occluded values using a pairing design t-test. The calcualted t = 6.94 is greater than 1.70, p =0.05 for 32 DF; therefore, occluded TEWL appears significantly greater.

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The HL values at sites occluded for one hour are given in Table III. A randomized block analysis of variance was performed; since the calculated F=2.27 is less than 2.60 (that associated with P=0.05 for 10 and 19 DF, treatment and error mean square, respectively), there is no apparent significant difference between skin sites. Visual observation of the data (Table III) shows that the forearm column is inflated by a high value for infant no. 1; otherwise, the data are similar to the abdomen and buttock. The buttock data column appears similar to the abdomen column except for two values (subjects 1 and 8) which increase the mean considerably. The weak trend towards a significant difference (2.27 is close to 2.60) is apparently caused by only one or two subjects.

Since there was great individual variation in this regional TEWL–HL study and one or two subjects seemed to greatly effect the parametric analysis of the HL data, a non-parametric treatment appears justified.

Kendall coefficients of concordance were calculated for the normal TEWL, occluded TEWL, and HL data to ascertain if one regional area tended to be consistently higher (or lower) relative to the others. The regional values of each subject were numerically ranked high, low, or lowest and analysed according to Siegel (8).

Normal TEWL produced a Kendall coefficient (w)=0.140 with an associated sum of squares (s)=47.17. Since 47.17 is less than 78.0 (the s associated with P=0.05 for N=3 and K=13), there is no apparent significant difference between the three regions.

Post-occlusion TEWL produced w=0.047 with s=13.5. Since 13.5 is less than 71.9 (that associated with P=0.05 for N=3 and K=12), there is no apparent significant difference between the three regions.

Total hydrations produced w=0.405 with s=98. Since 98 is greater than 60.0 (that associated with P=0.05 for N=3 and K=11), there appears to be a significant trend between regions: the abdomen, forearm, and buttock seem to produce low, higher, highest HL, respectively, with the abdomen deviating the most from forearm and buttock.

Additional background infant information is provided (Table IV).

Table III. *Hydration level ($\mu g\ cm^{-2}$)*

Subject	Abdomen	Buttock	Forearm
1	123	374	1 274
2	27	56	33
3	39	60	47
4	114	142	230[a]
5	64	54	51
6	42	48	56
7	199	133	250
8	117	275	121
9	75[a]	77[b]	–
10	61	104	83
11	38	129	85
12	42	53	40
13	94[b]	155[b]	–
Mean	78.7	129.8	206.4
S.D.	±53.2	±104.9	±361.9
S.E.	±16.0	±31.7	±109.1

[a] Estimated datum, necessary for statistical manipulation.
[b] These data were cancelled when performing an analysis of variance as only one of the missing data from the forearm could be safely estimated. The datum estimated was selected by chance, Woolf (9).

Table IV. *Background information*

Infant no.	Sex	Body length (cm)	Birth weight (g)	Gestational age (weeks)	Postnatal age (days)	Skin temp. (°C)	Room temp. (°C)
1	M	52	3 480	41	1	34.0	25.0
2	F	50	3 360	40	1	35.0	25.0
3	M	51	2 980	41	2	33.5	24.5
4	M	57	4 120	41	4	35.0	23.5
5	F	50	3 220	41	1	34.0	24.0
6	M	52	3 380	40	4	34.5	24.5
7	F	49	3 500	40	4	32.0	24.5
8	M	55.5	3 880	40	1	33.8	24.0
9	F	53	3 540	40	1	26.5	24.5
10	M	50	3 050	41	2	35.0	24.5
11	F	50	3 610	39	1	36.0	25.0
12	M	54	3 100	40	1	34.0	24.0
13	M	50	3 100	40	1	34.5	24.0

DISCUSSION

Normal skin TEWL. The normal TEWL measurements from the abdomen, buttock, and forearm in the present study appear similar (as well as the post-occlusion TEWL) regardless of the statistical methods utilized. This is in partial conflict with Hammarlund et al. (3) where the ventral forearm and buttock TEWL are similar (mean close to 9.0 g $m^{-2}h^{-1}$), but abdomen TEWL appears much lower. Graphical extension of their standard error ranges to two standard errors (encompassing 96% of the mean distribution) produces little or no overlap between abdomen TEWL and forearm or buttock TEWL; a significant difference is apparent. The present abdomen TEWL, while not significantly different, has the lowest mean (Table I). Perhaps the abdomen TEWL discrepancy is due to sampling error; experimental repetition may show more agreement. Visual comparison of the present means with those of Hammarlund et al. (3) (Table V) shows that the abdomen TEWL are close but the present forearm and buttock TEWL are half as great. The forearm and buttock difference probably does not result from the equipment used, as the electrolytic analyzer (Meeco) measurements should theoretically be higher, rather than lower. The Meeco method is affected by accidental atmospheric contamination and the facilitation of skin evaporation from the use of dry nitrogen (at 100 cc min^{-1} the water baseline is 30–35 ppm); this should tend to increase TEWL. The evaporimeter method is affected by ambient relative humidity (see Fig. 3, Hammarlund et al. 3); the high relative humidities (50–52%) employed with the evaporimeter should produce lower TEWL than the Meeco. The evaporimeter requires static air around the site sampled in order to read accurately; turbulence decreases the measurement instead of increasing it (communication with Servo-Med). Measurement of the same infants with both methods seems necessary before the forearm and buttock differences can be explained.

Hydration level. The abdomen, forearm, and buttock HL produced a strong trend towards differing significantly with parametric analysis; this seemed an artifact produced by one or two individuals. Non-parametric analysis substantiated the trend; the difference appeared significant with the abdomen HL much lower than the forearm and buttock. The difference in HL appears identical with that in TEWL between similar anatomic regions in Hammarlund et al. (8).

Post-occlusion TEWL. The post-occlusion TEWL were significantly greater than the normal TEWL, which supports the observation that hydrated stratum corneum allows more water diffu-

Table V. *Regional means and one S.E.: Present study and Hammarlund et al. (3)*

Study	Abdomen	Forearm	Buttock
Present	510.7±38.8	583.0 ± 54.2	539.2± 47.9
Hammarlund	380.0±75.0[b]	400.0[a] ±180.0[b]	910.0±200.0[b]

[a] Mean estimated by graphical extraction.
[b] S.E. estimated by graphical extraction.

sion than does dry, by Scheuplein & Blank (7). A return to normal TEWL is assumed once the stratum corneum dries to its original state in equilibrium with atmospheric humidity.

The buttock appears similar to the forearm for TEWL and HL; consequently the integrity of the respective regions of stratum corneum appears identical. According to this logic, study on the more accessible forearm may extend in application to the buttock.

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