J Wound Ostomy Continence Nurs. 2023;50(1):19-25.
Published by Lippincott Williams & Wilkins

Prospective, Case-Control Study Evaluating Effects of No-Sting Liquid Barrier Film on Skin Condition and Maturation of Stratum Corneum in Premature Neonates

NCPD 2.5 ANCC Contact Hours

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ABSTRACT

PURPOSE: To assess effects of a no-sting liquid barrier film (NSLBF) on the skin condition and maturation of the stratum corneum in premature neonates.

DESIGN: This was a prospective, case-control study with each subject serving as their own control.

SUBJECTS AND SETTING: The sample comprised 33 neonates, between 23 and 32 weeks of gestational age (GA). Participants received care in a level 4 neonatal intensive care unit in the northeastern United States. Data were collected between May 2018 and May 2019.

METHODS: All participants had NSLBF applied to their left chest, left abdomen, and left anterior and posterior upper thigh. The right side was left untreated and served as self-control. Measurements of skin pH, hydration, transepidermal water loss (TEWL) and Neonatal Skin Condition Scores were obtained on both the untreated right and treated left sides of the body over a 14-day period on days 1, 3, 7, and 14.

RESULTS: Worsening skin condition scores were observed on the treated side on days 7 and 14. There was an improvement in TEWL on the treated side, manifested as decrease in TEWL values. There was no difference in pH. At all points in time hydration was lower on the treated side.

CONCLUSIONS: Worsening skin condition scores and hydration status on the treated side indicate an altered or delayed process of skin maturation. These findings suggest that no-sting liquid barrier (NSLB) application should be limited to skin under medical devices, dressings, tapes, and affected areas. In addition, we recommend allowing adequate intervals to allow physiologic stratum corneum maturation between applications of NSLB.

KEY WORDS: Hydration, Immature skin, Liquid film barrier, Moisture barrier, Stratum corneum, Transepidermal water loss.

INTRODUCTION

When compared to their full-term counterparts, infants born prematurely are at greater risk for skin irritation and breakdown, due to the structural and functional immaturity of the skin at birth and within the first few weeks of life. Extremely preterm newborns have thin, dysfunctional, and vulnerable stratum corneum (SC) with only 2 to 3 layers of corneocytes.[1,2] Preterm babies also lack adequate SC lipid matrix, which is paramount for epithelial (barrier) function, resulting in "leaky" and weak SC cohesion. These lipids, and especially the long-chained free fatty acids and ceramides, are essential for maintaining adequate permeability of water across the SC, signaling functions inherent to cell proliferation, programmed cell death (apoptosis), and SC build-up.[3] The dermis in preterm newborns is only 30% to 40% as thick as the dermis of full-term newborns with a minimal reticular layer, a paucity of collagen, and poor cohesion to the epidermis due to fewer, shorter, and straighter connecting fibrils.[1-3] Subcutaneous tissue is minimal or absent, predisposing the infant to edema, an increased risk for absorption of toxins, and pressure injury.[2]

Premature infants are subjected to multiple procedures that cause epidermal stripping due to adhesive devices, which further compromises skin integrity and increases the risk for infections. Skin protection in vulnerable premature infants has traditionally been a challenge. Several products and concepts have been used and studied, but few have gained a prominent place in clinical practice. Moreover, few healthcare facilities have existing protocols that specify care of preterm skin, partially due to limited evidence or lack of consensus regarding best practices. There is a growing need to develop effective and safe techniques that offer protection from a growing number of medical devices and adhesives used in these neonates that fail to impair or (ideally) enhance skin integrity by encouraging development of the neonate's skin.

Transepidermal water loss (TEWL) is often used as a surrogate for measuring SC integrity.[1,4] Application of topical emollients has been shown to reduce TEWL, stabilize electrolyte and fluid

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DOI: 10.1097/WON.0000000000000938

status, and retain heat and energy to enhance overall growth.[5] A number of studies have shown that the use of emollients can decrease the frequency of dermatitis or improve skin integrity in very premature newborns. Nevertheless, caution must be exercised in the use of emollients in premature newborns due to an increased risk of nosocomial bacterial and fungal infections.[5-7]

Skin care in premature infants historically focused on treating of areas of cutaneous irritation and erosion, rather than prevention. Fortunately, a growing body of evidence now exists surrounding the clinical effects of newer products for skin protection, such as no-sting liquid barrier films (NSLBFs).[8-11] The aim of an NSLBF is it to mimic the skin's natural barrier function and prevent skin damage or facilitate repair of damaged skin.[8] An NSLBF used in our study is an acrylate-based formulation that is swabbed onto the skin and forms a uniform film that dries quickly, forming a non-sticky, breathable, and waterproof barrier.[9-11] An NSLBF aids in the protection of intact or damaged skin from irritants, moisture, caustic exudate, and removal of adhesives.[11] Additionally, these products provide an interface between the epidermis for applying dressings and adhesive tapes, important for preterm skin given the weak epidermal-dermal interface versus the stronger adhesion that often forms between an adhesive medical device and epidermis.

The NSLBFs have been used in patients with fecal or urinary incontinence, peristomal irritant contact dermatitis, moisture-associated skin damage of the skin adjacent to a wound due to exposure to exudate, and skin protection under adhesive dressings. The neonatal community is slowly adopting use of NSLBFs for prevention of skin problems, especially epidermal stripping, a subtype of medical adhesive-related skin injury (MARSI).[12,13] Although consensus documents and guidelines have incorporated the use of NSLBFs for adults who are at risk for breaches in their skin integrity, no such consensus exists for premature infants; rather, a search of the literature suggests that evidence supporting the use of NSLBFs in premature infants is anecdotal. While no guidelines in neonatal skin care, consensus-based best practice recommendations for prevention of MARSI recommend considering skin polymers and other topical epidermal products as a preventive intervention.[12] Therefore, the aim of this study was to evaluate the effects of an NSLBF agent on skin condition and physiologic SC maturation in premature infants.

METHODS

We used a prospective, case-control study design to guide data collection and analysis. The study setting was Cohen Children's Medical Center in Queens, New York. Infants admitted to the neonatal intensive care unit (NICU) were recruited from May 2018 to May 2019. The study was approved by the Northwell Health Institutional Review Board (IRB approval #17-0864, approved November 26, 2017). Parents/guardians of all eligible infants admitted to the NICU were approached to participate in the study, and if they agreed, written consent was obtained. Study subject inclusion criteria included infants less than or equal to 32 weeks' gestational age (GA), less than 30 days postnatal age, and those with the expectation of remaining in the NICU for at least 14 days. Infants were excluded if they were diagnosed with a congenital skin disorder.

The sample size of 30 patients used in this study was based on feasibility and availability of resources, and not on a formal power calculation. Of the 30 infants whose parents provided written consent, 30 satisfied the inclusion criteria and were enrolled.

Instruments

Demographic and pertinent clinical data were collected using a form developed for purposes of this study. The following data were collected for each participant: GA, birth weight, gender, and day of life at enrollment.

Control/untreated and treated skin areas were compared over 14 days using the Derma Lab USB Combo instrument (Derma Lab USB, Cortex Technology, Hadsund, Denmark; Figure 1). Three different probes were used to measure hydration, TEWL, and skin pH. The noninvasive skin probes for measuring each study outcome were gently placed over the skin surface, and software application modules obtained measurements that were presented in standardized units. Each measurement was completed 3 times at each site. Specifically, hydration, TEWL, and skin pH were measured on days 1, 3, 7, and 14. Each site received 3 measurements for each study outcome, for a total of 9 measurements per side per day. Multiple measurements were completed to enable calculation of an average value to ovoid outliers, values at each of the 3 measurements were added, and an average value calculated. Each probe was held in place between 3 and 5 seconds to obtain a value based on the manufacturer's directions for instrument use. Two primary investigators (V.B. and T.D.) obtained all measurements. Both were trained by the device manufacturer on correct use of the instrument and its probes. We acknowledge that normal values have been reported, but they differ based on GA, day of life, environmental factors, and area of the body. In order to control for these multiple potentially confounding factors, each participant served as their own control.

Transepidermal water loss is measured using an open-chamber probe that works by the principle of diffusion gradient. The range of TEWL measured varies from 0

Figure 1. Instrument used to measure SC pH, hydration, and TEWL. SC indicates stratum corneum; TEWL, transepidermal water loss.

to 250 g/m^2/h. The probe contains 2 humidity/temperature sensors in a 10-mm cylindrical diffusion chamber. The probe also measures environmental temperature and relative humidity; TEWL is recorded as the difference between the 2 vapor pressure gradient measures. Hydration is determined by a probe that measures conductance or capacitance; the possible range of values is 0 to 9999 micro Siemens range. The probe contains 8 pins designed to minimize moisture accumulation. Cutaneous pH is measured via a flat-surface glass probe that uses an electrochemical technique to quantify concentration of hydrogen ions. Measurements were calibrated daily against standard solutions of both acidic and basic pH.

In addition to obtaining 3 objective measurements, the 2 primary investigators (V.B. and T.D.) independently completed the Neonatal Skin Condition Score (NSCS). The NSCS is a validated instrument developed by the Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN); it is used in our facility with permission from the AWHONN.[14] The instrument comprises 3 domains: skin dryness, erythema, and breakdown. Each domain is scored from 1 to 3, with cumulative scores ranging from 3 to 9. Each domain was scored according to the following scale. A score of 1 on the dryness domain indicates normal skin moisture, a score of 2 indicates dry, visible scaling, and a score of 3 indicates very dry skin. A score of 1 on the erythema domain indicates no erythema, a score of 2 signifies visible erythema affecting less than 50% of the body surface, and a score of 3 indicates visible erythema more than 50% of the body surface. A score of 1 on the skin breakdown domain indicates no breakdown, a score of 2 indicates localized areas of skin breakdown, and a score of 3 indicates extensive skin breakdown. A cumulative score of 3 on the NSCS was deemed normal, whereas scores 4 or more indicated worsening skin condition. Scores were obtained and entered by the 2 primary investigators. If possible, the same primary investigator assessed a given infant at all measurement time points.

Study Procedures

A liquid polymer skin protectant (Cavilon No-Sting Barrier Film, 3M Health Care, St Paul, Minnesota) was applied to the left chest, left abdomen, and left anterior and posterior upper thigh serving; the same sites on the right side were left untreated and used as comparators enabling participants to act as their own controls. The dose, route of administration, and interval of administration adhered to the manufacture's general recommendations for use. The NSLBF was applied to the skin in 1 swipe; we used 1 to 2, 1-inch × 1-inch wipes saturated with the skin protectant. If an area was missed, the nurses were instructed to let the first layer dry for 30 to 40 seconds and only then go back to cover the missed area. Skin folds were separated during drying. The NSLBF was applied every 2 days. The dose, route of administration, and interval of administration adhered to the manufacture's general recommendations for use. The treatment area was not cleaned prior to application, as this is not something we would normally do. We aimed not to change normal unit practice. Studied areas were not exposed to devices/urine.

Outcomes were measured at days 1, 3, 7 and 14; we allowed a maximum variability of 1 day for completing outcome measurements. Measurements were performed during routine neonatal care and were done only if the infant was deemed as stable. A total of 2160 measurements were collected. Temperature and humidity were adjusted according to the unit's protocol. Humidity during the first week following delivery varies between 70% and 60% depending on GA; it is weaned to 50% by week 2 or sooner and to 40% after 14 days or sooner. All study measurements including NSCS and pH/TEWL and hydration took place while this protocol was in place.

Data Analysis

For the NSCS for each day and each location, the Wilcoxon signed-ranked test was used to examine whether there was a difference between the treated and untreated regions. When analyzing skin pH level, hydration, and TEWL, repeated-measures analysis of variance (RM-ANOVA) was used to analyze within-subjects efforts to determine an association between treatment group and that outcome based on day (1, 3, 7, and 14), anatomical location (chest, abdomen, and thigh), and treatment (NSLBF and no treatment). There was no between-subjects effect. For each outcome, the 3-way interaction of day by anatomical location by treatment, and all possible 2-way interactions (day by anatomical location, day by treatment, and anatomical location by treatment), were included in all models. Interactions were removed if they were not significant ($P < .05$). Tables have been included that provide the adjusted back-transformed means for each level of each effect along with the associated 95% confidence intervals for each outcome. This analysis provides information on the magnitude of the differences found.

When analyzing skin pH, a log transformation was used. Due to the nonlinear nature of the log transformation, once the back transformation has been applied, the mean difference on the original scale is a ratio of the 2 means, and is therefore unitless.

When analyzing skin hydration a square root transformation was used. Due to the nonlinear nature of the square root transformation, it is not possible to back transform the difference between the 2 means along with its associated 95% confidence interval.

All analyses were carried out using SAS Version 9.4 (SAS Institute Inc, Cary, North Carolina) by Northwell's statistician. Results were considered significant at an α level of .05. Due to the exploratory nature of this study, no adjustment for multiple testing was made.

TABLE 1.
Summary Statistics for Birth Weight, Gestational Age, and Day of Life

Label	n	Mean	Standard Deviation	Median	Minimum	Maximum
Birth weight, g	30	989.17	299.53	960.00	530.00	1530.00
Gestational age, wk	30	27.95	2.43	28.55	23.10	31.40
Gender, female/male	18/12					
Day of life (at enrollment)	30	1.87	1.31	2.00	0.00	6.00

TABLE 2.
Summary Statistics for Skin Condition Score by Side, Day, and Location[a]

Day	Location	n	Left Side Median (Minimum, Maximum)	Right Side Median (Minimum, Maximum)	Difference Left-Right Median (Minimum, Maximum)	*P* Value
1	Chest	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	1.000
	Abdomen	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 0.0)	–[b]
	Thigh	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 0.0)	–[b]
3	Chest	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	.5000
	Abdomen	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	.5000
	Thigh	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	1.0000
7	Chest	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	.0010
	Abdomen	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	.0020
	Thigh	30	3.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	.0020
14	Chest	29	4.0 (3.0, 4.0)	3.0 (3.0, 4.0)	0.0 (0.0, 1.0)	.0001
	Abdomen	29	4.0 (3.0, 4.0)	3.0 (3.0, 4.0)	1.0 (0.0, 1.0)	<.0001
	Thigh	29	4.0 (3.0, 4.0)	3.0 (3.0, 4.0)	1.0 (−1.0, 1.0)	.0005

[a]The no-sting liquid barrier film (NSLBF) was applied to the left side of the chest, abdomen and thigh; the right side acted as a control (no NSLBF applied).
[b]There were no differences between treated and untreated for any subject, and therefore, no statistical tests could be examined.

RESULTS

Thirty neonates (18 females and 12 males, 23-31 GA [appropriate for GA 27.9] with birth weights 530-1530 g [appropriate birth weight 989]) were enrolled (Table 1). Table 2 summarizes NSCSs based on the assessment of the skin dryness, erythema, and breakdown. There were no statistically significant differences in the mean NSCS between the treated left side and the untreated/control side on days 1 and 3. However, on day 7, there were significant differences between the treated side and the control/untreated side on the chest, abdomen, and thigh. Also on day 14, there were significant differences between the treated side and the untreated/control side on the chest, abdomen, and thigh. Of the 3 areas of the NSCS, dryness and skin breakdown (in the form of desquamation) contributed most often to the higher mean scores on the treated side.

Analyses of skin pH are summarized in Table 3 and Figure 2. No significant interactions were found and they were all removed from the model. Therefore, only the main effects of day, anatomical location, and treatment were examined. Analysis indicated significant differences based on day, but no difference due to anatomical location. No differences were found based on skin managed with NSLBF versus no treatment.

TABLE 3.
pH Results

Effect	Level	Adjusted Mean (95% CI)	*P* Value
Day	1	5.60 (5.47, 5.73)	.0156
	3	5.47 (5.35, 5.59)	
	7	5.65 (5.52, 5.78)	
	14	5.77 (5.64, 5.90)	
Location	Abdomen	5.59 (5.48, 5.70)	.0863
	Chest	5.56 (5.44, 5.67)	
	Thigh	5.73 (5.62, 5.84)	
Side	Left	5.69 (5.60, 5.78)	.0553
	Right	5.56 (5.47, 5.65)	

Analyses of skin hydration are summarized in Table 4 and Figure 3. No significant interactions were found and they were all removed from the model. As a result, only the main effects of day, anatomical location, and treatment were examined. Log transformation was used to better meet the assumptions of the RM-ANOVA model. Summary statistics (least square means and associated 95% confidence intervals) were calculated on the log scale, and then anti-logged in order to express the data on the original scale. There was a significant difference due to day. Significant differences were found based on anatomical location use of NSLBF versus no treatment. Least square means and the associated 95% confidence intervals are given in Table 4 and Figure 3.

Analyses of TEWL are summarized in Table 5 and Figure 4. No significant interactions were found and they were all removed from the model. As a result, only the main effects of day, anatomical location, and treatment were examined. The data were transformed by taking the square root, in order to better meet the assumptions of the RM-ANOVA model. Summary statistics (least square means and associated 95% confidence interval) were calculated on the transformed, and then squared in order to express the data on the original scale. Analysis found significant differences due to day and treatment (use of no-sting liquid barrier [NSLB] vs no treatment). Analysis revealed no significant differences due to anatomical location.

DISCUSSION

Study findings indicate that repetitive cutaneous application of NSLBF every other day was associated with a slightly worse skin condition score (mostly exemplified by dryness, tackiness, and desquamations) than control skin areas. The application of NSLBF had no effect on pH, positive effects on TEWL, and negative effect on hydration relative to the untreated control side. Considered collectively, these findings may indicate alterations in the process of SC maturation when a liquid barrier is applied.

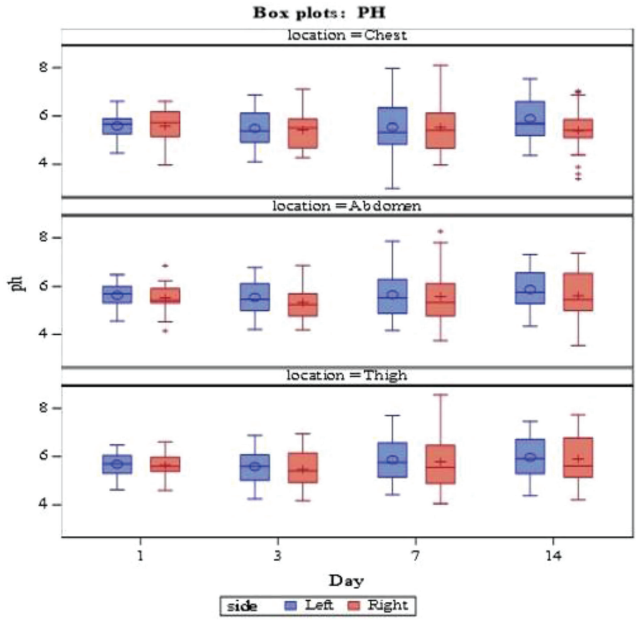

Figure 2. Box plot distribution of pH values by day, location, and side. The circle in the center of the box represents the mean, the line in the center represents the median, the top and bottom of the box are the 25th and 75th percentiles of the observed values, and the upper and lower fences represent the most extreme values.

The NSLBF used in this study is a polymeric solution intended for the protection of intact or damaged skin. As it dries, it creates a durable film barrier that is transparent, with good oxygen and moisture vapor permeability. The film is dispersed in a nonstinging solvent; evidence shows it is noncytotoxic and has low dermatitis potential.[8,11] It should not be applied to an infected area or near an ignition source because it is flammable in the wet form. Care should also be taken when the NSLBF is applied near the nasal orifice or eyes. Nevertheless, we have not found any problems when applying the NSLBF to the nasal columellar area to minimize friction coefficient with noninvasive respiratory devices, including application in small neonates at 23-week GA.

Brandon and colleagues compared an NSLBF to an ointment-based skin protectant (Aquaphor, Beiersdorf Inc, Hamburg, Germany) on TEWL and skin integrity in neonates, including older premature infants.[15] They found that both products were equally effective. This is the only other study to our knowledge that studied an NSLBF skin protectant in neonates.

Similar to our findings, Brandon and colleagues[15] observed increased dryness associated with application of an NSLBF. They hypothesized that the appearance of dry and peeling skin was created by residue from the liquid polymer acrylate rather than actual skin dryness.[16] We agree that the perception of dryness is partially due to the matte residue left by the NSLBF if a thick layer is applied or if a previously applied layer had not completed desquamated before the new layer is applied (in a neonate normal outer epidermal layer desquamation takes place every 2-3 days). However, we further hypothesize that increased skin desquamation and perception of dryness may also be related to an alteration in the process of natural physiologic maturation; this hypothesis is informed by knowledge that decreased hydration also results in increased desquamation.

After birth, exposure to a dry extrauterine environment leads to comparatively rapid structural and functional maturation of the SC.[17] Animal studies have demonstrated that the magnitude of hydration and TEWL are related to the rate of SC maturation, including synthesis of SC components, SC proliferation, and functional integrity. Maturation usually occurs in 4 to 10 weeks, depending on GA.[13] Neonatal skin responds with a rapid increase in hydration over the first 2 weeks; the process then slows but continues to progress over the first year of life as the function of the eccrine glands matures.[14] Hydration of the SC is regulated by filaggrin, a protein present in corneocytes that is converted to water-binding, small free amino acids; these molecules comprise approximately 40% of natural moisturizing factors (NMFs). The NMF molecules attract water molecules and maintain skin hydration. Excessive humidity or abnormal architecture of the SC due to dryness and desquamation can dysregulate production of the NMFs.[1,4] It is unknown whether continuous presence of a liquid barrier on the skin affects filaggrin proteolysis and production of natural NMFs.

Transepidermal water loss is the amount of water loss through the epidermis through evaporation over time; TEWL is influenced by multiple factors.[14,18] Preterm neonates may experience clinically relevant water loss via TEWL; increasing relative humidity in the environment will slow TEWL and subsequent water loss. Nevertheless, findings from a study of neonates by Agren and colleagues[19] found that while very high humidity (>75%) slowed TEWL versus neonates cared for in an environment with 50% humidity, the more humid environment also impeded maturation of the SC and its moisture barrier function. Similarly, application of an impermeable membrane to injured skin also shows to inhibit restoration of the epithelial barrier of the SC; this adverse effect did not occur when a semipermeable dressing was applied.[20] Our findings shows that frequent application of a semipermeable liquid barrier to immature skin decreases insensible water loss and TEWL; however, the NSLBF also slows cutaneous hydration, and may slow SC maturation (similar to the effect of high humidity). Both of these findings are clinically significant to the care of premature neonates.

Lack of a hydrophobic mantle (vernix) in preterm neonates also impairs skin hydration status along with its acid mantle.[7,21] The acidic pH of the skin depends on presence of lactic acid, free amino acids, and fatty acids on the SC surface. Skin acidification is essential for the epidermal barrier maturation

TABLE 4.
Hydration Results

Effect	Level	Adjusted Geometric Mean[a] (95% CI)	*P* Value
Day	1	374 (330, 424)	<.0001
	3	285 (251, 324)	
	7	229 (202, 260)	
	14	251 (220, 285)	
Location	Abdomen	322 (178, 360)	.0100
	Chest	267 (239, 298)	
	Thigh	254 (228, 284)	
Side	Left	225 (206, 246)	<.0001
	Right	347 (317, 380)	

[a]Mean and 95% confidence interval were calculated on the log scale and anti-logged in order to express the data on the original scale of measurement.

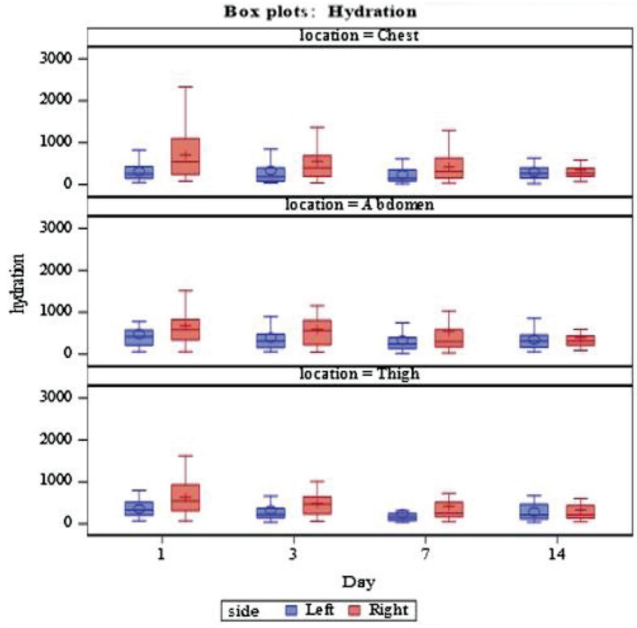

Figure 3. Box plot distribution of hydration values by day, location, and side. The circle in the center of the box represents the mean, the line in the center represents the median, the top and bottom of the box are the 25th and 75th percentiles of the observed values, and the upper and lower fences represent the most extreme values.

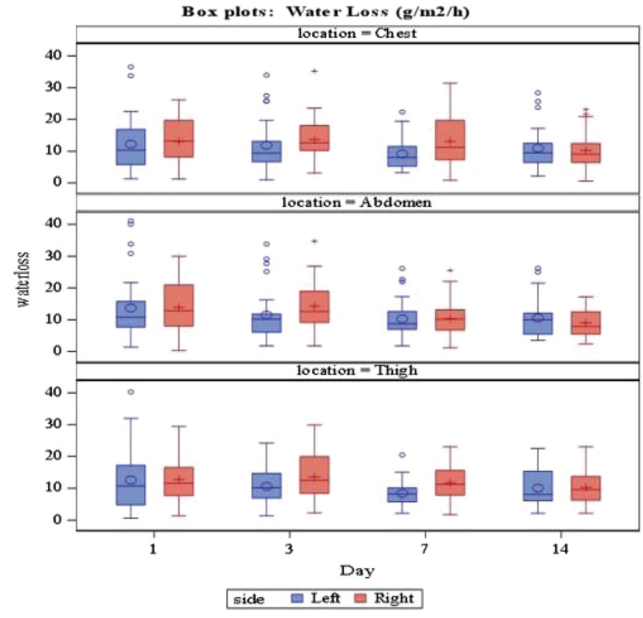

Figure 4. Box plot distribution of TEWL values by day, location, and side. The circle in the center of the box represents the mean, the line in the center represents the median, the top and bottom of the box are the 25th and 75th percentiles of the observed values, and the upper and lower fences represent the most extreme values. TEWL, transepidermal water loss.

and repair process.[22] A more alkaline (higher) pH is known to enhance desquamation.[23] In addition, preterm neonates do not naturally possess great quantities of filaggrin.[24] In the absence of sufficient filaggrin breakdown products, pH rises, and this rise if exacerbated by diminished organic acids.[14] Studies have demonstrated the important slow physiologic decrease in skin surface pH over the first few weeks in preterm and term neonates, and the importance of the physiologic acidification process.[22-25] Our findings indicate that application of an NSLBF did not impede normal pH evolution. We assert this finding is clinically relevant, because impedance of SC acidification would be undesirable in the already infection-prone preterm population.

Even though the NSLBF is easy to apply, dries quickly, is compatible with devices, and subjectively well-tolerated (as noted by our staff via pain scores, vital signs, and behavioral observations of babies), our results raise questions. While application of the NSLBF improved (decreased) TEWL, findings also revealed a concerning association with a worsening NSCS and slower development of SC hydration. The NSCS indicated visibly worsening of the skin condition by days 7 and 14 on the NSLBF treated side, which was mainly manifested as dryness, tackiness, and desquamation. It is plausible to hypothesize that, despite positive TEWL effects, the liquid barrier applied every other day slowed hydration acquisition, important in the "normal" skin barrier maturation process, while impairing formation of the skin's NMF. Decreased formation of NMF leads to increased SC keratinocyte turnover and increased desquamation, leading to farther decreased hydration level and dryness. Longer interuse interval may minimize the observed effects. Also, judicious drying of the NSLBF after application may alleviate the visual perception of skin dryness.

TABLE 5.
Transepidermal Water Loss Results

Effect	Level	Adjusted Geometric Mean[a] (95% CI)	*P* Value
Day	1	11.65 (10.68, 10.66)	.0008
	3	11.56 (10.60, 12.57)	
	7	9.76 (8.87, 10.68)	
	14	9.36 (8.48, 10.29)	
Location	Abdomen	10.59 (9.79, 11.43)	.8111
	Chest	10.73 (9.92, 11.57)	
	Thigh	10.35 (9.56, 11.18)	
Side	Left	9.95 (9.31, 10.60)	<.0152
	Right	11.19 (10.51, 11.89)	

[a]Mean and 95% confidence interval were calculated on the square root and squared in order to express the data on the original scale of measurement.

Implications for Practice

Based on study findings, we propose that liquid barrier application is valuable in prevention of MARSI and moisture-associated skin damage and recommend "spot-specific" application of the NSLBF under devices, dressings, tapes, and affected areas. We further recommend a 3-day interval between applications to allow timely physiologic maturation of the SC.

Strengths and Limitations

Our study provides much needed data on the effects of an NSLBF in premature neonates less than 32-wk GA. We were able to provide much needed data on preterm neonates younger than 30 days and as young as 23-week GA and follow SC maturation parameters longitudinally, over 14 days. Limitations include data collection at on a single unit, and lack of a power analysis guiding sample size. We acknowledge that the side for application of the NSLBF was not randomly

allocated. We made this decision out of concern that were the application versus control sites randomized, it would not have been feasible for the nurses to keep track of which side should be treated. Nevertheless, we acknowledge that this decision introduced bias into the study. In addition, the evaluator was aware of which side was treated, and which was not. This knowledge may not have affected the measurement of pH level, hydration, and water loss measured by a technologic device it may have affected NSCSs, and the erythema score in particular. In addition, *P* values were not adjusted for multiple comparisons; therefore, study findings should be interpreted with caution.

CONCLUSIONS

We evaluated the effects of application of an NSLBF on neonatal skin over a period of 14 days. We found that skin condition scores were lower on areas treated by the NSLBF on days 7 and 14 when compared to the nontreated areas. We also found an improvement in TEWL on the treated side, and no differences in pH. At all points in time hydration was lower on the treated side; decreased skin hydration implies poor SC integrity. Delayed development of SC hydration on the NSLBF treated side also raises the question of the optimal interval between applications of the NSLBF and whether it should be applied to intact, device-spared skin or reserved for injured areas and skin under adhesives/devices only. We therefore recommend application of the NSLBF every 3 days based on natural desquamation frequency of neonatal epidermis (3-4 days) and based on our results of increased dryness/desquamation (evident by increased NSCS with every second day application). We believe that every other day application is excessive.

ACKNOWLEDGMENTS

We acknowledge and are grateful to Ms Nina Kohn for her work with statistical analysis for the study. We also would like to thank Dr Maria Battaglia for her help with data collection.

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