Impact of Urine on Diapered Skin Health

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Summary

Proper hygiene of diapered skin has long been recognized as essential for maintaining healthy baby skin. In particular, the effective removal of urine and feces from baby skin is necessary to maintain an intact skin barrier against external irritants and minimize the incidence of diaper rash.[1] Although the combination of feces and urine causes the most severe skin damage,[2,3] urine alone is sufficient to trigger skin irritation.[4]

A recent survey on the use of baby wipes revealed that some caregivers do not clean diapered skin if the diaper change involves the presence of urine only.[5] This review describes the impact of urine exposure on baby skin to highlight the importance of good skin hygiene practices for maintaining healthy baby skin. Basic knowledge of urine composition and unique properties of baby skin are first reviewed to describe how urine interacts with and impacts baby skin. Then, potential harmful effects of specific urine constituents and benefits of using appropriately formulated baby wipes are discussed in detail to inform diapering practices that promote healthy baby skin.

Background: Urine and Baby Skin

Newborn bladder function is not mature at birth and continues to develop throughout infancy.[6] The frequency and volume of urination change with increasing bladder maturity and capacity.[7] Detailed metrics on bladder capacity and frequency of urination during infancy are described in Table 1. In general, babies urinate 15-20 times per day with a mean void volume of approximately 60 mL during the first year of life.[7,8]

Table 1. Bladder capacity and urination frequency during infancy

Age	Bladder Capacity (mL)	Urination Frequency per Day
Preterm baby (32 weeks)	12	22-24 times
Full term baby	50	22-24 times
1 year old	70	12-15 times
2 years old (pre-potty trained)	70	12-15 times
3 years old (post-potty trained)	120	3-7 times

Modified from Sillén et al, 2004.

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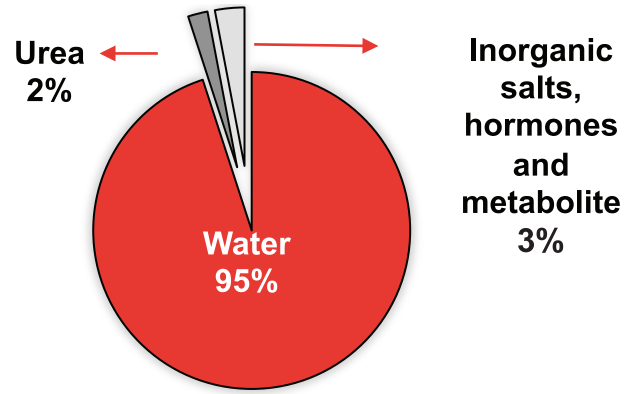

Figure 1. Composition of human urine.

The composition and properties of human urine, both in health and disease, have been topics of extensive study. It has long been known that the composition of human urine is primarily water (95%), while the remaining constituents are urea, uric acids, salts (Na, K, Cl, P), and trace amounts of hormones and metabolites (Figure 1).[9] However, advanced analytical technologies have recently been applied to urine analysis, enabling the identification of more than 3000 metabolites in human urine[10] and providing new insights on urine composition and its impact on skin health. Normal urine pH in healthy babies and adults is neutral to slightly acidic, typically pH 6-7.[9] Physiological ranges of urine osmolality have been reported as 50-600 mmol/L in preterm and up to 800 mmol/L in full term babies.[11]

Although basal skin barrier function of healthy full-term babies seems competent for survival in a terrestrial environment at birth, physical properties of infant skin are quite different from those of adults, as summarized in Table 2. The size (volume and surface area) of corneocytes from baby skin is 20% smaller than those derived from adult skin and the stratum corneum is 30% thinner than in adults. Corneocytes are dead skin cells that normally reside within the outermost layer of the skin, the stratum corneum, and play a key role in the skin's barrier function. Infant skin has higher surface pH (especially in newborns), lower sebum secretion, and higher transepidermal water loss (TEWL), indicative of diminished barrier properties.[12] However, infant skin continues to mature—especially during the first year of life. For example, acid mantle formation, which plays a pivotal role in barrier augmentation, rapidly develops during the first month after birth.[12,13] It is clear that the skin microbiome evolves considerably in parallel with skin maturation following birth.[14] Taken together, these intrinsic factors result in baby having less resilient skin barrier function compared to that of adults.[12]

Table 2. Different characteristics of baby skin vs. adult skin

Characteristics	Baby Skin	Adult Skin
Epidermis		
Corneocytes (surface area & volume)	Small	Large
Stratum Corneum Thickness	Thin	Thick
Pigmentation	Less	More
Natural Moisturizing Factor	Less	More
pH	High (first month)	Low
Sebum	Less	More
Transepidermal Water Loss	High	Low
Dermis		
Collagen fiber density	Less	More
Papillary-to-reticular dermis transition	Not clear	Clear

Modified from Telofski et al., 2012.

In addition to these intrinsic properties, diapered baby skin is frequently exposed to various extrinsic challenges. The main risk factors for diaper dermatitis include: overhydration, mechanical friction, and urine- and fecal-derived skin irritants.[2,4,15] In particular, overhydration caused by prolonged urine exposure results in the outermost layers of the skin (stratum corneum) softening and weakening (maceration), thereby making the skin more susceptible to physical damage (i.e., friction) and irritant penetration.[2] Warner et al. demonstrated how overhydration disorganized the physical barrier structure of skin using transmission microscopy.[16] A simplified illustration describing those changes is provided in Figure 2, which includes: swelling of corneocytes; abnormal formation of large pools of water in intercellular spaces; disrupted intra-corneocyte lipid bilayer structure; and degradation of corneodesmosomes, which are the inter-/intra-cellular structures required for corneocyte adhesion.[16,17] In addition to these structural changes, clinical data suggest that increased skin pH is positively correlated with skin wetness.[18] This correlation was also found in an *in vitro* skin equivalent culture,[19] suggesting that high humidity may disturb acid mantle formation in skin. This is important because acid mantle formation is critical to maintaining intact barrier function. Moreover, increased skin pH is known to promote the growth of harmful microorganisms, including *Candida albicans*, *Staphylococcus aureus*, and various streptococci.[20] Finally, high humidity has been shown to alter skin microflora.[21]

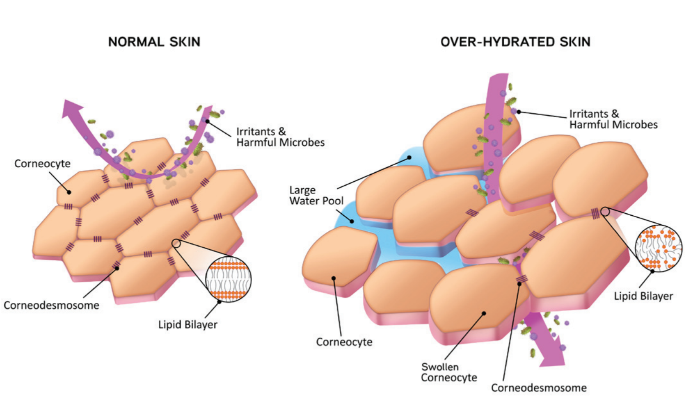

Figure 2. Skin barrier disruption caused by overhydration.

Relative to adults, baby skin is more susceptible to the intrusion of pathogens and various irritants due to both intrinsic properties and extrinsic challenges.[18,22] Therefore, diaper area cleansing should be effective enough to remove potential irritants but gentle enough to preserve the skin barrier function.

Diapered Area Cleansing Following Urination: Importance and Benefits

Removing Potential Skin Irritants in Urine

Exposure to urine alone contributes less to diapered skin irritation than exposure to feces or urine and feces combined,[2,3,15] however, urine components are not benign to skin health. Berg et al. explored the role of urine in the development of diaper dermatitis and found that urine increases the permeability of diapered skin to irritants and can directly irritate skin when exposure is prolonged.[4] This harmful effect was not due to overhydration, as the effect of urine exposure was significantly higher than that of water (Table 3), suggesting that certain urine components accelerated skin barrier damage. The underlying mechanism has not been determined, but on possibility is that inorganic salts in urine may cause barrier damage by altering the skin electrolyte balance. Thus, if skin is not properly cleansed at each diaper change, accumulation of excess salts on the skin surface may lead to elevated TEWL, indicative of compromised skin barrier integrity.

Table 3: Skin permeation following water or urine exposure

Treatment	Permeation of ^3H_2O (CPM; Mean ± SD)
Occlusion only	12,975 ± 5,900
Water	17,563 ± 5,414
Baby urine	290,245* ± 24,600

Modified from Berg et al., 1986[4] *$p \leq 0.05$ vs other treatments. Hairless mice were patched with baby urine, water, or dry patches. After 10 days of exposure, the area of skin was excised and placed on a penetration chamber as described by Cooper et al., 1984.[23] Permeability of the skin was determined by measuring the penetration of a tracer molecule (^3H_2O) through the skin.

Except water, urea is the most abundant component (2%) of urine. It has been suggested that urea alone does not trigger significant skin irritation;[4] however, feces is a source of the enzyme urease that produces ammonia from the urea present in urine. Thus, concurrent or subsequent exposure of urine-contaminated skin to feces can cause hydrolysis of urea to ammonia, increasing skin pH and causing skin damage. Thus, prompt removal of urine from the skin should help to maintain the ideal pH of diapered skin.

The composition of the remaining 3% of urine (beyond water and urea) seems to be much more diverse than previously understood. As mentioned previously, Bouatra et al. identified more than 3000 metabolites in human urine in a recent metabolomic study.[10] Chemical subclasses and the number of metabolites in each category are described in Table 4. Given that urine is 95% water by weight and hydrophilic in nature, it is surprising that 866 different lipid molecules (hydrophobic) are present in urine. In addition, urine also contains trace amounts of bile acids. Additional research is required to explore the potential effects of these metabolites on diapered skin.[10]

Eliminating Odor

Residual urine on baby skin often produces unpleasant odors derived from the breakdown of urea to ammonia and other volatile constituents. Thus thorough skin cleaning is necessary not only for promoting skin health, but also for preventing the emanation of odors from baby skin.

Table 4: Chemical classes in a urine metabolome database

Chemical Class	# of Compounds Identified
Aromatic Compounds	1233
Lipids	866
Amino Acids, Peptides, and Analogues	286
Aliphatic Acyclic Compounds	199
Carbohydrates and Carbohydrate Conjugates	116
Organic Acids and Derivatives	108
Polyketides	74
Nucleosides, Nucleotides, and Analogues	49
Alkaloids and Derivatives	45
Homogeneous Metal Compounds	45
Others	58

Modified from Bouatra et al., 2013.[10]

Providing Proactive Skin Care Using Appropriately Formulated Baby Wipes

Proper skin cleansing during diaper changes will not only effectively remove potential irritants, but can also protect skin from subsequent exposures to feces.[20] Despite the common perception, many clinical studies have demonstrated that use the of premoistened commercial baby wipes is safe and better for maintaining healthy baby skin when compared to cleansing regimens that use only water.[24,25,26] Potential benefits of disposable wipe use have been reviewed,[27,28] which have identified important skin health attributes as effective removal of skin irritants, balancing physiological skin pH, and applying emollients to protect baby skin from friction and subsequent exposures to urine and/or feces. In discussing the importance of baby wipe formulation development, Cunningham et al. suggested that the ideal composition provides skin care benefits to sensitive baby skin. For example, aqueous solutions used in baby wipes are usually formulated to have a final pH in the range of 4.5-6.5 and provide a buffering capacity to balance skin surface pH, thereby augmenting barrier integrity.[29,30] Baby wipe formulations often include emollients such as behenyl alcohol, stearyl alcohol, stearic acid and triglycerides that may promote healthy baby skin by providing lipid-like properties that protect the skin surface from excessive hydration and harmful insults.[30] Therefore, baby wipe use after urination should be strongly encouraged, not only for cleansing purposes (removing irritants and preventing bad odor), but also to provide proactive skin care protection in anticipation of subsequent exposures to feces.

Conclusion

Prolonged skin exposure to urine and feces is the primary cause of diaper dermatitis. It has been reported that 50% of babies experience this inconvenient skin irritation at some point during the first year of life.[2] The incidence and severity of diaper rash can be effectively reduced through consistent use of optimal hygiene practices at each diaper change. Urine exposure can significantly disturb baby's sensitive skin, disorganizing barrier structure of the uppermost skin layer (stratum corneum), and altering skin pH and composition. Potentially harmful effects of residual inorganic salts and other compounds, including those recently identified in the technical literature, cannot be overlooked. Removing sources of odor from baby skin is another obvious benefit in addition to skin health. Thus, thorough skin cleansing using gentle premoistened baby wipes is strongly recommended with each diaper change as part of an optimal skin care regimen.

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