

Potential Allergens in Disposable Diaper Wipes, Topical Diaper Preparations, and Disposable Diapers: Under-recognized Etiology of Pediatric Perineal Dermatitis

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Background: Allergic contact dermatitis in young children may be an under-recognized cause of perineal dermatitis. The diapered infant skin is uniquely susceptible to allergic contact dermatitis because of more permeable neonatal skin, a moist environment, frequent contact with irritants and resultant skin barrier breakdown, and exposure to topical products such as diaper wipes, diaper preparations, and disposable diapers. To our knowledge, potential allergens in these products have not been thoroughly catalogued or studied.

Objective: We explore and review potential allergenic ingredients in diaper wipes, topical diaper preparations, and disposable diapers.

Method: We analyzed 63 diaper wipes, 41 topical diaper preparations, and the 3 top selling diaper brands available from two of the largest retailers in the United States. Each potential allergen is discussed, and epidemiologic studies of rates of sensitization to potential allergens in children are also reported.

Conclusions: Botanical extracts, including members of the Compositae family, were the most commonly represented potential allergen in both diaper wipes and topical preparations. Other potential allergens identified with high frequency include α -tocopherol, fragrances, propylene glycol, parabens, iodopropynyl butylcarbamate, and lanolin. Frequent culprits such as formaldehyde releasers and methylchloroisothiazolinone/methylisothiazolinone were not prevalent in our analyzed products.

Allergic contact dermatitis (ACD) is increasingly recognized as a cause of persistent perineal (bathing suit distribution) dermatitis in the diapered pediatric population. It was once thought to be uncommon because of the initial false belief that ACD does not occur in children because of lack of chronic exposure to allergens and an immature immune system. It was not until 1985 that the first large study examining the rate of sensitization in children was performed, which found a 20% sensitization rate.¹ In 1999, a European review of existing patch testing study in children found that 14.5% to 70.7% of children with suspected ACD had a positive patch test.² The first US-based study in children found a 77% clinically relevant sensitization rate at 2

major referral centers.³ The North American Contact Dermatitis Group (NACDG) demonstrated that 62.3% to 65.7% of children referred for patch testing had positive reactions confirming that ACD is equally prevalent in children as in adults and young children (<5 years), and there was a higher relevant positive patch test (RPPT) rate compared with adults.^{4,5} The top 10 contact allergens in children (aged 0–18 years) based on RPPT reaction are listed in Table 1.⁵

Perineal dermatitis (PD) is a common dermatologic problem in children accounting for a large number of visits to pediatric dermatologists.⁶ The prevalence of PD varies across the world depending on diapering practices, products used, and hygiene. One large retrospective study in the United Kingdom estimated the prevalence of PD to be 25% in the first 4 weeks of life.⁷ The most frequent cause of PD is irritant contact dermatitis caused by long-term exposure to moisture and irritants present in urine and feces leading to maceration and breakdown of the skin barrier.⁶ Irritated and damaged skin is highly susceptible to sensitization by potentially allergenic compounds found in frequently used diapering products including topical diaper preparations and disposable diaper wipes. Several recent case reports implicated components of diapers and reagents used in the diaper wipes and preparations in cases of allergic PD in young children.^{8–13} The exact prevalence of allergic PD is

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TABLE 1. Most Common Diapering Product Contact Allergens Found in Children (aged 0–18 years)

Allergen	Relevant Positive Patch Test (%)
Balsam of Peru, 25% pet	5.5
Lanolin alcohol, 50% pet	5.1
Fragrance mix, 8% pet	4.9
Formaldehyde, 1% aq	2.9
Quaternium-15, 2% pet	2.9

Adapted from Zug et al.⁵

aq indicates aqueous vehicle and pet, petrolatum vehicle.

unknown. There are few reported cases in the literature and a lack of large well-organized multicenter studies on perineal ACD, which precludes meaningful systematic reviews.

We present a detailed analysis and discussion of potential allergens found in all diaper wipes and preparations available online at Walgreens (Walgreens Co, Deerfield, Ill.), the largest drugstore chain in the United States. We also examined the disclosed ingredients of the 3 top selling diaper brands available online at Amazon (Seattle, Wash.). Potential allergens are discussed in light of available epidemiologic patch test studies in children.^{4,5,14}

METHODS

We examined 63 available disposable diaper wipes and 41 topical diaper preparations available online from Walgreens as of November 2015. A comprehensive list of disposable wipes available was found on the Walgreens online catalog (home < shop < baby, kids, and toys < diapering < baby wipes) with 112 available products. Sorting through the products and carefully removing duplicates resulted in 63 different disposable diaper wipes. The topical diaper preparations were selected in a similar manner (home < shop < baby, kids, and toys < diapering < diaper rash treatments). Initially, 56 products were available but after removing duplicates and identical products, 41 different topical diaper preparations were included in our analysis. The ingredients of diaper wipes and diapering creams were obtained from Walgreens (www.walgreens.com) and the individual product manufacturer's website. The online ingredients of 5 randomly selected disposable diaper wipes and 5 topical diaper preparations were validated with the actual package without discrepancies.

We selected the top 3 bestselling diaper brands from Amazon (www.amazon.com) based on sales data. Diaper component materials and ingredients were obtained either from the manufacturer's website, product packaging, or through personal communication with a sales representative via e-mail or messaging. The names of the diaper manufacturers are not disclosed.

Potential allergens that are part of the NACDG standard series and also present in the diaper wipes, topical preparations, and diapers were extracted and tallied. Emerging potential allergens not included in the NACDG standard series were also extracted based on expert opinion of coauthors J.T., B.B., and K.C.

RESULTS

Potential allergens in 63 disposable wipes are listed in Table 2. The most common potential allergens were botanical extracts (Table 3), which we define as plant-derived products including essential oils, extracts, and waxes, present in 60 of 63 diaper wipes. The most common botanical extract is *Aloe vera*, present in 50 of 63 diaper wipes. Compositae extracts are seen in 27 of 63 diaper wipes and of these, derivatives of *Matricaria chamomilla* or chamomile (24/63) is most common followed by *Calendula officinalis* (marigold) and *Helianthus annuus* (sunflower), each observed in 4 of 63 and 3 of 63 disposable wipes, respectively. *Melaleuca alternifolia* (tea-tree oil) is seen in 3 of 63 diaper wipes and *Lavendula angustifolia* (lavender) in 3 of 63 diaper wipes.

α -Tocopherol acetate (vitamin E) is the second most common potential allergen (40/63) in disposable wipes followed by fragrances (21/63), iodopropynyl butylcarbamate (13/63), propylene glycol (13/63), benzyl alcohol (12/63), and parabens (6/63). Ethylhexylglycerin was observed in 5 of 63 wipes.

Formaldehyde-releasing preservatives such as bronopol (3/63) and quaternium-15 (1/63) were infrequently observed, as were the preservatives methylisothiazolinone (MI) (4/63) and methylchloroisothiazolinone (MCI) (1/63). Lanolin was observed in 5 of 63 diaper wipes and the surfactants cocamidopropyl betaine

TABLE 2. Potential Allergens in Disposable Diaper Wipes and Topical Diaper Preparations

Potential Allergens	Observed Frequency in Disposable Diaper Wipes (n = 63)	Observed Frequency in Topical Diaper Preparations (n = 41)
α -bisabolol	2 (3.2)	2 (4.9)
Benzyl alcohol	12 (19.0)	2 (4.9)
Benzoic acid	3 (4.8)	2 (4.9)
Botanical extracts	60 (95.2)	30 (73.1)
Bronopol	3 (4.8)	Not observed
Cocamidopropyl betaine	2 (3.2)	Not observed
Decyl glucoside	5 (7.9)	Not observed
Diazolidinyl urea	Not observed	1 (2.4%)
DMDM hydantoin	5 (7.9)	Not observed
Ethylhexylglycerin	5 (7.9)	3 (7.3)
Fragrances	21 (33.3)	18 (43.9)
Iodopropynyl butylcarbamate	13 (20.6)	Not observed
Lanolin	5 (7.9)	17 (41.5)
Methylchloroisothiazolinone	1 (1.6)	Not observed
Methylisothiazolinone	4 (6.3)	Not observed
Myroxylon pereirae	Not observed	5 (12.2)
Parabens	6 (9.5)	10 (24.4)
Propylene glycol	13 (20.6)	6 (14.6)
Quaternium-15	1 (1.6)	Not observed
Sorbitan sesquileate and derivatives	Not found	6 (14.6)
α -Tocopherol acetate	40 (63.5)	15 (36.6)

Values are number (percentage).

TABLE 3. Potential Allergens of Botanical Origin Found in Diaper Wipes

Potential Botanical Allergens	Observed Frequency in Disposable Diaper Wipes (n = 63)	Observed Frequency in Topical Diaper Preparations (n = 41)
<i>A. vera</i>	50 (79.4)	11 (26.8)
<i>A. mellifera</i>	Not observed	19 (46.3)
<i>C. officinalis</i>	4 (6.3)	9 (22.0)
<i>H. annuus</i>	3 (4.8)	5 (12.2)
<i>L. angustifolia</i>	3 (4.8)	5 (12.2)
<i>M. chamomilla</i>	24 (38.1)	6 (14.6)
<i>M. alternifolia</i>	3 (4.8)	2 (4.9)

Values are number (percentage).

(CAPB) and decyl glucoside were seen in only 2 of 63 and 5 of 63 wipes, respectively. *Myroxylon pereirae* (MP) was not observed.

Potential allergens in 41 different topical diaper preparations (creams, ointments, and lotions) were identified and listed in Table 2. The most common potential allergens are botanical extracts (30/41) of which beeswax from *Apis mellifera* or the western honeybee (19/41) is most prevalent followed by *A. vera* (11/41) (Table 3). Compositae extracts are seen in 13 of 41 topical diaper preparations of which *C. officinalis* (9/41) is the most common followed by *M. chamomilla* (6/41) and *H. annuus* (5/41). *Lavendula angustifolia* is seen in 5 of 41 topical diaper preparations, and *M. alternifolia* is observed in 2 of 41.

Other potential allergens in the topical diaper preparations include fragrances (18/41), lanolin (17/41), α -tocopherol acetate (15/41), parabens (10/41), and propylene glycol (6/41). Ethylhexylglycerin was present in 3 of 41 topical preparations. Formaldehyde-releasing preservatives were uncommon, with diazolidinyl urea present in only 1 of 41 topical products analyzed. *Myroxylon pereirae* was present in 5 of 41 topical preparations.

The construction among the 3 topselling diapers is very similar including the use of polypropylene for the breathable top sheet of the diaper, polyethylene or polyurethane for the back sheet, super absorbable polymers made of sodium polyacrylate and wood pulp for the core, and adhesives and elastic for the waistband (Table 4).

The primary differences include the choice to use perfume in the diapers and whether or not to include lotions in the top sheet.

DISCUSSION

Perineal dermatitis is one of the most common complaints presenting to a pediatrician or pediatric dermatologist.⁶ Perineal dermatitis begins with trapped moisture leading to maceration, frequent and prolonged exposure to irritants within urine and feces and skin cleansers, and a highly alkaline environment.¹⁵ The differential diagnosis for PD in children is broad and includes irritant contact dermatitis, ACD, infections (candida, staphylococcus, and streptococcus), psoriasis, seborrheic dermatitis, acrodermatitis enteropathica, and Langerhans cell histiocytosis. Allergic contact dermatitis as a cause of PD may be under-recognized. However, recent case reports^{8,9,12,16,17} and data from large multicenter studies support that allergic PD may be under-recognized.^{4,5} This is not surprising given the plethora of products associated with care for the modern baby, from the diaper, to diaper creams, wet wipes, topical medicaments, materials in toilet training seats, and toilet seat cleaners.¹⁸ Further confounding the issue is that consumers may be misled by the terms *hypoallergenic*, *dermatology tested*, *pEDIatrician approved*, and *all natural* because they lack standardization. Ingredients in products have specific purposes such as fragrances to help with the odor of excretions or preservatives to prevent microbial contamination. Virtually all commercially available diapering products contain a range of ingredients, and our aim is to highlight potential allergens in commonly used products so that practitioners can explore the possibility of ACD in children with PD.

Allergic Contact Dermatitis to Disposable Diaper Wipes and Topical Diaper Preparations

The care for a diapered infant is complex. More than 90% of caretakers in the United States currently report using disposable wipes¹⁹ and most providers recommend the application of topical creams or ointment with each diaper change to prevent and treat irritant diaper dermatitis. Although studies have supported the

TABLE 4. Ingredients of Popular Diaper Brands in the United States

	Brand A	Brand B	Brand C
Top sheet	Polypropylene	Polypropylene	Polypropylene
Back sheet	Polyethylene	Polyethylene	Polyurethane
Color	Pigment	Pigment	Pigment
Absorbent core	Processed wood pulp Cellulose tissue Absorbent gelling material	Wood cellulose fiber Sodium polyacrylate	Unbleached wood pulp Sodium polyacrylate
Waistband	Elastic	Synthetic rubber	Polymer spandex
Fastener	Adhesives	Adhesives	Adhesives
Lotion	Petrolatum <i>Aloe barbadensis</i> extract Stearyl alcohol	Petrolatum <i>A. barbadensis</i> extract	None
Fragrance	Perfume	Fragrance free	Fragrance free

safety and efficacy of diaper wipes and topical preparations in decreasing diaper-area erythema and maintaining skin hydration,^{15,20} there may be a tradeoff in that these products may occasionally lead to allergy.

Botanical Extracts

Botanical extracts were the most common potential allergens in both disposable wipes (95.2%) and topical preparations (73.1%), although epidemiologic patch test data in children for many of these potential allergens do not exist. The most common botanical potential allergen found in disposable wipes is *A. vera* (79.4%), shown to improve diaper dermatitis in small studies²¹ with few reported cases of ACD.²² Most causes of aloe sensitization occur from homemade aloe that includes the bark of the aloe leaves, which contain antrachinones, a known irritant and allergen.²³

Beeswax is the most common botanical extract in topical diaper preparations (46.3%). Allergic contact dermatitis to purified beeswax is rare and usually caused by propolis, a possible contaminant.^{24,25} Cross-sensitivity between propolis and beeswax has been found to be 7%;²⁶ avoidance of products containing beeswax should be considered with a positive patch test (PPT) reaction to propolis.

Chamomilla recutita (German chamomile) and *C. officinalis* are the second most common potential allergens of botanical origin found in disposable diaper wipes and topical preparations, respectively. Chamomile and marigold are used for their skin-calming properties²⁷ but ACD has been reported.^{28–30} Linalool, which is one of the European Union's top 26 fragrance allergens, is found at a concentration of 0.3% in chamomile.³¹ Chamomile and marigold are members of the Compositae family, which contains the most common flowering plants to cause ACD because of sensitizing alcohols and oils including sesquiterpene lactones (SL) and α -bisabolol.²⁸

An RPPT reaction to Compositae and SL mix is reported in 2.4% and 4.9% of children younger than 5 years,⁵ respectively, and reaction to the Compositae mix is more prevalent in children with atopic dermatitis (AD).³² α -Bisabolol, an essential oil with cross-reactivity to SL, is a primary active ingredient in chamomile. Allergic contact dermatitis to α -bisabolol has been reported to topical emollients.^{33,34} In our analysis, α -bisabolol is found in only 2 of 63 disposable wipes and 2 of 41 topical preparations. Although patch testing data for chamomile are not available in children, there is a high cross-sensitization rate in patients with a PPT reaction to the Compositae mix and to chamomile.³⁵

Helianthus annuus is a Compositae member observed in 4.8% of diaper wipes and 12.2% of topical preparations and a potential allergen likely due to SL. Sunflower seed extract is used in the formulation of topical diaper preparations and wipes to prevent PD and to soothe the skin. Rare cases of ACD caused by helianthus seeds have been reported,³⁶ and in one Danish study, 56% of patients with Compositae allergy were also sensitized to sunflower seed extract.³⁶

Lavendula angustifolia is used for its antimicrobial, fragrant, and healing properties and was named Herb of the Year by the

International Herb Association in 1999. Allergic contact dermatitis to lavender is most common in aromatherapists and massage therapists.³⁷ Lavender was identified in 12.2% of topical preparations and just 4.8% of diaper wipes. Five percent of children aged 0 to 5 years were found to have a PPT reaction to lavender but none were relevant.⁵ In all children aged 0 to 18 years, the RPPT rate to lavender was 0.7%.⁵ The increasing popularity of lavender essential oil in personal care products may contribute to the rising rates of ACD. In a Japanese cohort, the percentage of PPT reaction to lavender increased from 1.1% in 1990 to 13.8% in 1998 likely because of the increased popularity of lavender.³⁸

Melaleuca alternifolia is used in many personal care products for its antiseptic and aromatherapy properties³⁹ with few reports of ACD.⁴⁰ In Australia where tea-tree oil originates, 1.8% of the population have PPT reaction to *Melaleuca alternifolia*.⁴¹ Tea-tree oil was found in 4.8% of diaper wipes and 4.9% of topical preparations. Between 2005 and 2012, no children younger than 5 years had an RPPT reaction to tea-tree oil, but the RPPT rate of all children younger than 18 years was 0.4%.⁵ Therefore, tea-tree oil sensitization may be low in children as of 2015, because few topical diapering products use tea-tree oil. However, the prevalence of ACD to tea-tree oil may increase with its increasing use in young children.

α -Tocopherol Acetate

α -Tocopherol acetate is frequently added to diapering products for its antioxidant, wound healing, and skin moisturizing properties. It is the second most common potential allergen in diaper wipes, present in 63.5% of reviewed products and 4th most common in topical diaper preparations with a prevalence of 36.6%. Although generally under-recognized as an allergen, 4.9% of young children aged 0 to 5 years reacted to α -tocopherol acetate,⁵ although there are no reports of PD to α -tocopherol acetate in the literature.

Fragrances

Fragrances, including essential oils and MP, are used in diapering products to impart a pleasant scent and mask unpleasant odors. We found fragrances in 33.3% of diaper wipes and 43.6% of topical diaper preparations. Fragrances as a group are one of the most common causes of ACD in young children although infrequently cited as a cause of perineal ACD.⁴² This may be because of under-recognition or under-reporting. The RPPT rate for fragrances in children younger than 5 years was 7.3% for MP, 4.9% for fragrance mix I, and 2.7% for fragrance mix II.⁵ Other fragrances such as ylang-ylang oil and limonene did not elicit an RPPT reaction in children younger than 5 years.⁵

Myroxylon pereirae is a top 10 allergen in children⁵ and found infrequently in our analysis (5/41 topical preparations and 0/63 disposable wipes). However, fragrances frequently contain components found in MP including benzoic acid, cinnamic acid, cinnamic alcohol, cinnamic aldehyde, cinnamyl cinnamate, eugenol, farnesol, and isoeugenol.

Although some products will openly label fragrances in the ingredients, others list individual fragrance components such as

linalool making it difficult for the consumer to identify fragrances. Fragrances and cross-reactors of fragrances can also be used as preservatives (covert fragrances), in which case they do not need to be identified as fragrances and may be included in *fragrance-free* products.

Benzyl alcohol and its oxidized metabolite, benzoic acid, are constituents (and cross-reactors) of MP and are included in numerous cosmetic products as a preservative, solvent, and fragrance. In our analysis, benzyl alcohol was in 19% of diaper wipes and 4.9% of topical diaper preparations.^{43,44} However, sensitization for benzyl alcohol is low, with a 0% RPPT rate in children younger than 5 and 0.1% in children younger than 18 years.⁵ Benzoic acid is found in 3 (4.8%) of 63 disposable wipes and 2 (4.9%) of 41 topical preparations in our analysis. The prevalence of benzoic acid contact dermatitis in children is unknown but presumed to be low from previous studies and case series.⁴⁵

Preservatives

Preservatives are used in wet disposable wipes and topical diaper preparations to prevent microbial contamination and are one of the most common causes of perineal ACD.⁴⁶ The American Contact Dermatitis Society has named 2 preservatives Allergens of the Year: formaldehyde in 2015⁴⁷ and MI in 2013.⁴⁸ In response to medical concerns and public perception, there have been industry shifts in the types of preservatives used in personal care products. This leads to a decreased incidence of ACD to previous allergens and the emergence of new potential allergens.

Iodopropynyl butylcarbamate (IPBC) is the most commonly found potentially allergenic preservative identified in our sampling of disposable diaper wipes (20.6%). The rate of RPPT to IPBC increased from 2007–2008 to 2009–2010.⁴⁹ It has low sensitization risk and allergic reactions are uncommon,⁵⁰ but IPBC has been implicated in ACD because of baby wipes⁵¹ and cosmetic removal wipes.⁵² Patch testing to IPBC in children only showed a 0.6% positivity in children younger than 18 years; in children younger than 5 years, IPBC did not cause any RPPT reaction.⁵ Although the sensitization risk to IPBC is higher in leave-on products,⁵³ we did not identify any topical preparations with IPBC.

Parabens are one of the oldest and most frequently used preservatives in food and cosmetic products with increasing rate of sensitization,⁵⁴ although still low among commonly used preservatives. This is also true among children, where RPPT reactions are seen in 0% of children younger than 5 and 0.9% of children younger than 18 years.⁵ In our analysis, parabens, predominantly methylparaben, are found in 9.5% of diaper wipes and 24.4% of topical preparations. There is a single reported case of infantile PD to paraben.⁵⁵ Much controversy has arisen over the safety of parabens in the last 20 years given its questionable relationship to breast cancer and potential hormonal activities.⁵⁶ Because of the negative media reports on parabens, some manufacturers have begun substituting for it a new preservative: ethylhexylglycerin.⁵⁷ Ethylhexylglycerin is found in 7.9% of disposable wipes and 7.3% of topical preparations. Few reports of ACD to ethylhexylglycerin exist in the literature,^{58,59} and the frequency of positive reaction to ethylhexylglycerin in

children is unknown. Ethylhexylglycerin has been recently added to the NACDG cosmetic panel⁵⁷ and should be on the watch list as an emerging allergen.

Methylisothiazolinone was named Contact Allergen of the Year in 2013 because of its increasing prevalence in personal care products since 2005.⁴⁸ Previously used in combination with MCI, MI is now found as a stand-alone preservative in personal care products. Perineal ACD in infants caused by MCI/MI and MI have been reported.^{12,60–62} The pattern of dermatitis can involve not only the perineum but also perioral skin because these wet wipes are often used to clean around the mouth in children.¹² In our study, MI is found in 6.3% of disposable wipes but not in topical preparations. Methylchlorisothiazolinone was seen in 1 brand of disposable wipes only and no topical preparations. The MCI/MI combination has been reported to be positive in 2.7% of children younger than 18 but in 0% of children younger than 5 years.⁵ This is likely to be under-representative of the true sensitization rate to MI in children because approximately 40% of patients with MI allergy are missed with patch testing to MCI/MI.⁴⁸ In another study, patch testing with MI demonstrated a positive rate in 6% of children younger than 5 years.⁶³ The low prevalence of MI and MCI in our reviewed products may reflect industry's awareness of reports of ACD.

Formaldehyde and formaldehyde-releasing chemicals (quarternium-15, imidazolidinyl urea, diazolidinyl urea, DMDM hydantoin, and bronopol) are used in the cosmetic and personal care industry as an antimicrobial preservative. In our analysis, 14.3% of diaper wipes contained formaldehyde releasers, most commonly DMDM hydantoin. Of the topical diaper preparations we analyzed, only 1 product contained a formaldehyde releaser: diazolidinyl urea. In children younger than 18 years patch tested for formaldehyde and formaldehyde-releasing preservatives, an RPPT reaction was detected in 2.9% to formaldehyde, 2.9% to quaternium-15, 1.8% to bronopol, 0.9% to DMDM hydantoin, 1.1% to diazolidinyl urea, and 0.8% to imidazolidinyl urea.⁵ Compared with adults, children were less likely to have an RPPT reaction to formaldehyde and its releasers except bronopol.⁵ Patients with AD are more likely to be sensitized to formaldehyde releasers than nonatopics.⁶⁴ In our analysis, formaldehyde and its releasers are not frequently used in diaper wipes or topical preparations and may have been replaced by preservatives with less allergenic potential.

Emulsifiers and Emollients

Propylene glycol (PG) is a solvent and emulsifier used in topical products and medicaments including 18.3% of topical corticosteroids.⁶⁵ Although considered to be a weak sensitizer, the rate of RPPT reaction to PG is increasing.⁴⁹ However, no RPPT reaction was identified in children younger than 5 years although 2.3% of children younger than 18 years tested positive.⁵ It is identified in 20.6% of wet wipes and 24.4% of topical preparations in our analysis. More recently, PG as an excipient in oral antihistamines has been implicated to elicit systemic ACD in adolescents sensitized to PG.⁶⁶ With increasing use, more cases of allergic PD caused by PG may be identified.

Sorbitan sesquioleate (SSO) and its derivatives are emulsifiers found in topical personal care products and topical medicaments, especially corticosteroids. Potential cross-reactors to SSO include sorbitan monooleate, sorbitan monostearate, polysorbate, and sorbitol.⁶⁷ It is considered a weak allergen, mostly causing sensitization in already damaged skin.⁶⁸ In a recent study of 112 patients referred for patch testing, 8.9% were allergic to SSO⁶⁹, which is significantly higher than the rates reported 20 years prior⁷⁰ and therefore may be an emerging allergen.⁶⁷ In our analysis, 14.6% of topical diaper preparations contained SSO or a cross-reactor whereas no diaper wipes included this potential allergen. One study found SSO and its cross-reactors to be in 28.3% of topical corticosteroids.⁷¹ Therefore, SSO and its cross-reactors can serve as increasingly important causes of ACD in children given its prevalence in commonly used topical corticosteroids and diaper preparations used on already damaged skin.

Lanolin is an emollient derived from sheep sebum and its true allergenic potential has been debated. There can be considerable variability in the manufacturing of lanolin leading to inconsistent estimates of lanolin sensitivity. The most allergenic component of lanolin is Amerchol L101, and many experts patch test to both lanolin alcohol and Amerchol L101 to truly capture the rates of lanolin ACD. Lanolin was represented in 7.9% of diaper wipes and 41.5% of diaper preparations in our study. In the NACDG study, 5.1% of children younger than 18 years were found to have an RPPT reaction to lanolin alcohol (50% in petrolatum), although 0% of children younger than 5 years had an RPPT reaction to lanolin alcohol.⁵ The results of the RPPT to Amerchol L101 were not available in the same NACDG study. In the European Surveillance System on Contact Allergies study, 2.67% of children aged 1 to 5 years had a PPT reaction to lanolin.⁷² Because of inconsistent results in patch testing to lanolin, most experts agree that testing to personalized products is important.⁷³

Surfactants

Decyl glucoside is a nonionic surfactant widely used in personal care products because of its low irritant potential. It is present in 5 of 63 of the analyzed diaper wipes but none of the topical preparations. Allergic contact dermatitis to decyl glucosides in sunscreen, soaps, and shampoos has been reported, and there is 1 case report of ACD to cetearyl glucoside (a cross-reactor) in hygiene wipes in an adult.⁷⁴ In children younger than 5 years, no RPPT reaction was seen to decyl glucoside.⁵ In children younger than 18 years, 2.3% had an RPPT reaction to decyl glucoside.⁵ Therefore, decyl glucoside may be a potential elicitor of PD from disposable wipes.

Cocamidopropyl betaine, Contact Allergen of the Year in 2004,⁷⁵ is a zwitterion used in personal cleansing products including shampoos (especially no tear), cleansers, soaps, and disposable wipes. The use of CAPB in personal products has increased exponentially because of the replacement of anion detergents with higher irritant potential than CAPB.⁷⁵ Some experts believe that the truly allergenic material in CAPB is dimethylaminopropylamine,⁷⁶ a precursor. Others believe that CAPB is not a significant

skin sensitizer, with most PPT results being false positives.⁷⁷ In our study, it was found only in disposable diaper wipes at a low prevalence rate of 3.2%. Current NACDG data estimate that the RPPT rate in children younger than 5 years to CAPB is 4.9% but 0% to dimethylaminopropylamine.⁵

Allergic Contact Dermatitis to Diaper Components

Because diapering practices and technology have evolved, the prevalence of severe PD across the world has decreased. This is in part because of the super-absorbent polymers (SAP) made of sodium polyacrylates found in commercial diaper cores that are able to absorb more than 30 times their weight in liquid waste, protecting the infant skin from overhydration. To date, there are no reports of ACD to SAP in diapers but to polyacrylates in incontinency pads in an adult.⁷⁸ Although ACD to acrylate monomers is not uncommon, acrylate polymers have a low sensitization rate because of their large molecular size. Contact sensation may occur because of the contamination of polyacrylate with acrylate monomers during the manufacturing process or incomplete polymerization and release of monomers.⁷⁸ Therefore, ACD to SAP in baby diapers may be under-reported. All of the 3 top selling diaper brands we analyzed contained SAP made of sodium polyacrylate.

Breathable outer covers of the diapers also help dissipate moisture from the infant skin to prevent skin maceration. Materials used for the top sheet and back sheet include polypropylene, polyethylene, and polyurethane (personal correspondence), which are common polymers used in the manufacturing of plastics. All of the analyzed diapers used a blend of these polymers for the outer covers. There are 2 case reports of ACD to polyethylene and polyurethane found in toilet seats although no reports exist of ACD to these polymers in diapers.^{79,80}

Elastic bands in diapers help provide a snug fit for infants and prevent leakage, but contain rubber, which is one of the most common sensitizers in children. Rubber undergoes vulcanization to cross-link raw rubber to add strength. To aid in the process of vulcanization, accelerators and retarders are added, which serve as potential contact allergens, including thiuram, mercaptobenzothiazole, and cyclohexylthiophthalimide. Dermatitis to elastic bands usually appears on the waist and inguinal folds and has been termed "Lucky Luke" dermatitis because of the holster-like distribution. Multiple cases are reported of contact allergy with PPT reactions to mercapto mix, mercaptobenzothiazole, and p-tertbutyl-phenol-formaldehyde resin (PTPFR) in the elastic bands of their diapers.^{8,10,11} We were unable to ascertain from the diaper manufacturers what chemicals were used in the process of making elastic bands.

Fasteners of diapers have also been implicated in ACD because of the adhesives they contain, including colophony (rosin) and PTPFR. Roul et al¹⁰ reported 3 children with PTPFR allergy. Furthermore, colophony has been reported to be present in all leading diapers in a Swedish study⁸¹ and between 2005 and 2012, colophony elicited an RPPT reaction in 1.2% of children younger than 18 years.⁵

Although disperse dyes have been reported as potential allergens in diapers,⁹ recent publications suggest that leading disposable diapers do not use disperse dyes and instead use nonsensitizing pigments, which reportedly are less sensitizing.⁸² Compared with disperse dyes, pigments are larger particles with lower potential for skin penetration.⁸² It is unknown what types of dyes are used by *nonleading* diaper manufacturers. None of the 3 leading diapers analyzed contained dyes. However, less popular and discounted diapers may contain disperse dyes and patch testing to this specific component of the diaper may be high yield if suspicion exists for contact allergy to dyes.

Fragrances are occasionally added to diapers to give a *baby fresh* scent because of parental preference.⁸³ Only 1 diaper brand in our analysis was found to contain fragrances, which is one of the most common and relevant allergens seen in young children. Patch testing to fragrance mix I, fragrance mix II, and MP demonstrated 4.9%, 2.7%, and 7.3% sensitization, respectively, in children aged 0 to 5 years.⁵ Sensitization to fragrances was also noted to be more prevalent in patients with AD^{84,85} and a key driver in sensitization to allergens in patients with AD.⁸⁶

LIMITATIONS

Our study had several limitations. We surveyed only 1 drug store's online catalogue in the United States during the month of November in 2015 for disposable diaper wipes and topical preparations. Bestselling diapers were identified using data from another top online retailer. There are dozens of disposable wipes, topical preparations, and diapers available on the market throughout the world and our study does not account for this. Product lines, ingredients, and frequency of potential allergens may change frequently and our study does not account for this. Furthermore, we hand-selected the most common potential allergens through expert opinion, and unknown, rare, potential allergens may be missed in our analysis. Emerging allergens with limited reports may also be missed.

Future Direction

Children and adults both experience ACD with the same prevalence although the frequency of RPPT results to specific top allergens may differ. There are limited studies available examining the true incidence of allergic PD in children, and this may be because of the false belief that children cannot have ACD or allergic etiologies are uncommon causes of PD. Epicutaneous patch testing remains the criterion standard for allergen identification. Because of the limited space availability on an infant's back, it may be necessary to select allergens based on history and location of the dermatitis. Therefore, the authors of this study are in the process of creating an abbreviated PD patch test panel for infants and children to include the most frequent potential allergens in topical products and known elicitors of perineal ACD. This patch test panel will be created using expert consensus of the members of the American Contact Dermatitis Society and available literature on frequent causes of allergic PD in children.

CONCLUSIONS

Allergic PD is infrequently reported in children although we believe that the incidence is higher than suspected. The RPPT rate is high in children among the most common pediatric allergens (Table 1)⁵ and the RPPT rate of potential allergens eliciting PD found in our analysis such as MP and Compositae mix increased between 2001 and 2012.^{4,5} The overall prevalence of ACD in children is also on the rise;⁸⁷ 63.2% of young children had 1 or more RPPT reactions in the 2005–2012 NACDG study compared with 40% in the 2001–2004 NACDG study.^{4,5} Although the NACDG studies of pediatric ACD are the largest of its kind, there are limited data on RPPT reactions of the less common potential allergens in diaper care although this may change with better referral and use of patch testing and the development of a supplemental diaper series we are proposing for this patient population.

In this study, we analyzed 63 disposable diaper wipes, 41 topical diaper preparations, and 3 topselling diaper brands available from leading consumer retailers in the United States and analyzed the frequency of potential allergens (Tables 2 and 4). We found botanical extracts, specifically Aloe and members of the Compositae family, as the most commonly represented potential allergens in both wipes and topical preparations (Table 3). Other potential allergens identified with high frequency included α -tocopherol, fragrances, PG, parabens, IPBC, and lanolin although the true allergenic potential of these additives remains to be seen. Frequently implicated causes of ACD in children such as formaldehyde releasers and MCI/MI were not prevalent in our analyzed products. Hidden sources of potential causes of perineal ACD in children include topical preparations and disposable wipes, and an effort should be made to patch test children with PD not just with screening panels but also their own products.

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