Review article

NEW CONTACT ALLERGENS AND EXPOSURES IN THE HOME AND ENVIRONMENT: AN UPDATE

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ABSTRACT

New chemicals are continually being introduced in consumer products such as cosmetics, pharmaceuticals, medical devices, textiles, tattoo inks, rubber materials and footwear. Allergic contact dermatitis (ACD) arising from new sensitisers in such items is a frequent problem in daily practice, and a correct diagnosis is often difficult. In this overview we provide a practical update illustrated by clinical examples of new and sometimes unexpected sensitisers and some old ones in new applications. Notable examples include the emergence of amino acid alkyl amides (AAAs), vitamin C compounds, resorcinol derivatives, glycols, metals (eg tin) and lipid/carbohydrate allergens in cosmetics; benzophenone residues in octocrylene-containing sunscreens, plastics and inks; the replacement of tosylamide/formaldehyde resin in nail varnishes by sensitising copolymers based on phthalic anhydride/adipic acid and (meth)acrylates; epoxy resin as a non-occupational contact allergen in domestically used glues; fragrances (including terpenes) in, for example, (medical) adhesives; persulfates in hot-tub detergents; isothiazolinones in leather wear and rubber gloves; chemicals such as chlorophenols in textiles and acetophenone azine in foot and sportswear; biguanides and quaternary ammonium salts used as antimicrobial agents in cosmetic and non-cosmetic products (eg wound-care products); acrylates and silicone components in medical devices.

Keywords: allergic contact dermatitis, cosmetics, medical devices, diagnosis, patch test

INTRODUCTION

Patch tests need to be performed on patients suspected of suffering from allergic contact dermatitis (ACD). We provide a practical overview of new contact allergens or new applications of already known sensitisers.

COSMETIC CONTACT ALLERGENS

SKIN-CARE PRODUCTS INCLUDING ANTI-AGING COSMETICS AND MAKE-UP

Various amino-acid alkyl amides (AAAs), derivatives of amino acids, are used as poly-functional ingredients (ie for various reasons) in cosmetics.[1] These include:

- oleoyl tyrosine (in tanning products);
- capryloyl glycine (in cosmetics, topical pharmaceuticals and medical devices, also used in the management of atopic dermatitis (AD));
- (isopropyl) lauroyl sarcosinate (in skin-care products, make-up and anti-acne treatments);
- sodium lauroyl sarcosinate and sodium myristoyl sarcosinate (in 'hypo-allergenic' hand and facial cleansers).

Most recently, sodium stearoyl glutamate (in a body and after-sun lotion)[2] and sodium lauroyl methylaminopropionate (in a shampoo)[3] were also added to this list.

Miscellaneous new sensitisers include:

- *Magnolia officinalis bark extract* and the related *Magnolia grandiflora bark extract*;[4]
- bakuchiol (an alternative for retinol in anti-aging products);[5]
- resveratrol;[6]
- tetrahydroxypropyl ethylenediamine (also an allergen in hand sanitisers);[7]
- caprylic/capric triglyceride;[8] and
- derivatives of sucrose (eg sucrose (di)stearate)[9] in anti-aging formulas and hydrating creams.

Vitamins and derivatives are increasingly incorporated in (anti-aging) cosmetic products.[10] Noteworthy are vitamin C (ascorbic acid) derivatives such as 3-0-ethyl-L-ascorbic acid,[11] 3-glyceryl-ascorbate[12] and tetrahexyldecyl ascorbate,[13] also often used in skin-lightening products, as are derivatives of resorcinol (butyl resorcinol, phenylethyl resorcinol).[14] Interestingly, patients sensitised to vitamin C compounds or to resorcinol derivates, often still tolerate the oral intake of vitamin C, or do not show any patch-test reactions to resorcinol, respectively. Derivatives of vitamin B5 in cosmetics ('skin soothing' and 'corticosteroid-free') and medical devices: beside panthenol (in hair and wound-care products), its impurity pantolactone[15] and the derivative calcium panthothenate[16] are also sensitisers.

Glycols are relatively rare and mainly pharmaceutical sensitisers, however, their potential allergenicity in cosmetic products

TABLE I: TEN EXEMPLARY OBSERVATIONS OF NEW COSMETIC SENSITISERS OR NEW APPLICATIONS THEREOF IN 2022

	CONTACT ALLERGEN	OBSERVATION
1	Oleoyl tyrosine	A derivative of the amino-acid tyrosine and a strong sensitiser in self-tanners, 'supertanners' and tan-enhancing cosmetics.
2	3-0-ethyl-L-ascorbic acid	A derivative of vitamin C (ascorbic acid), and a typical new sensitiser in skin-lightening and anti-aging cosmetics.
3	Caprylyl glycol	A preservative related to propylene and butylene glycol which, like pentylene glycol, has been highlighted as a new cosmetic sensitiser.
4	Cera alba	White beeswax or 'purified propolis', related to cera flava (CF, yellow beeswax), yet not necessarily co-reacting with these; an important cause of allergic contact cheilitis (ACC).
5	Tin (stannous)	A metal, increasingly found as tin (stannous) fluoride or tin (stannous) chloride in toothpastes and dental-care products, capable of provoking (angular) cheilitis and (aphthous) stomatitis.
6	Benzophenone	A very potent photosensitiser, related chemically to ketoprofen and other benzophenone derivatives, and the precursor/degradation product of the UV-filter octocrylene; present in octocrylene-containing cosmetics, and also in plastics and (magazine) inks.
7	Phthalic anhydride/adipic acid	Copolymers typically present in classic nail varnish, replacing tosylamide/formaldehyde resins.
8	Epoxy resin	A potential nail varnish allergen (tosylamide/epoxy resin) and increasingly present in domestically used glues (eg to create jewellery, art, herbariums).
9	Hydroperoxides of D-limonene	Terpenes used in several (non)-cosmetic products, also present in some types of colophonium, and in (medical) adhesives, even those claimed to be 'hypo-allergenic' (ie colophonium-free).
10	Persulfates	Hair-bleaching agents, also increasingly used as treatments for swimming pools, hot tubs and jacuzzis, capable of provoking immediate and/or delayed (nummular eczema-like) dermatitis.

might be underestimated: caprylyl glycol,[17] butylene glycol and pentylene glycol;[18] cross-reactivity with propylene glycol has not always been convincingly documented and deserves more research.

Shellac is found in mascara, lipsticks and hair spray, and recently has also been reported in non-cosmetic products[19] such as tattoo inks, mouth guards and food items – the latter two are responsible for cheilitis and hand dermatitis, respectively.

Cosmetic oils, fats and waxes[20] are causes of cheilitis, not only the *usual suspects* such as castor oil derivatives and lanolin (US Allergen of the Year 2023),[21] but also *Butyrospermum parkii* (shea butter), Candelilla cera (*Euphorbia cerifera*), Carnauba wax (*Copernicia cerifera*) and, especially, cera alba, the latter regarded as 'purified' propolis, yet not always co-reacting with it. Propolis itself, which was recently added to the European baseline series, causes facial dermatitis, cheilitis or contact stomatitis, as it can be present in both cosmetics and in herbal remedies and food or sweets. Carmine red,[22] a contact sensitiser in lipsticks; like shellac, it may occasionally provoke doubtful or irritant patch-test reactions.

Apart from lip cosmetics, dental-care products are also responsible for (angular) cheilitis and/or (aphthous) stomatitis. In Antwerp several such cases were due to tin (stannous) fluoride and/or tin chloride[23] in toothpastes (see Figure 1). Carvone is a mint derivative and an oxidation product of limonene, which, like menthol, peppermint and trans-anethole, can appear in toothpastes, mouth waters, adhesive pastes for dental prostheses, food and sweets; it may even induce oral lichenoid lesions.[24]

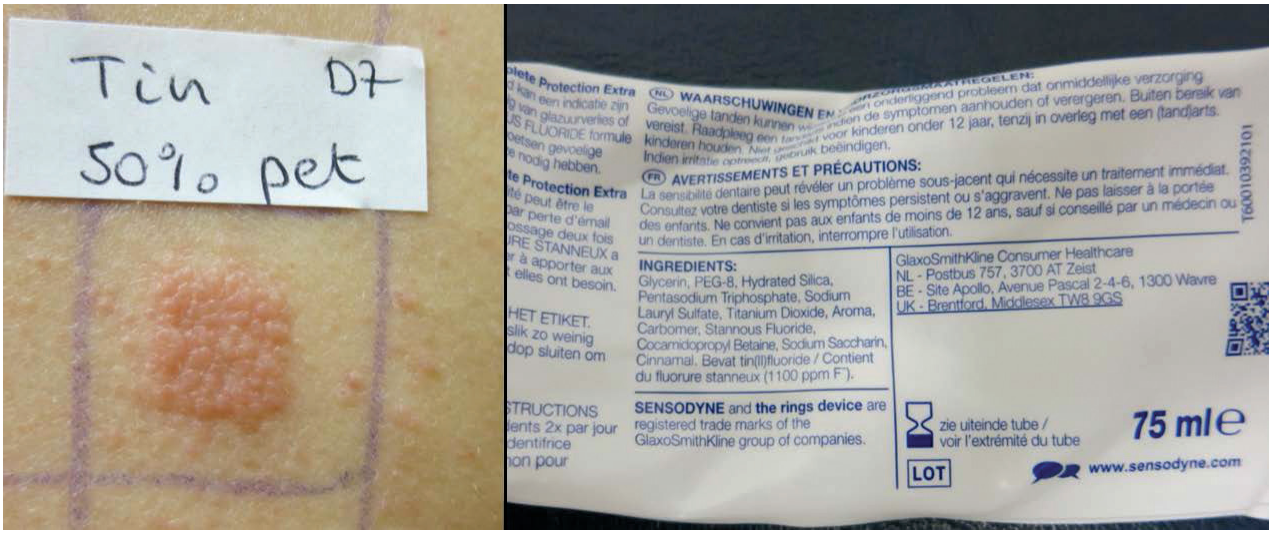

Figure 1: Strong positive patch-test reaction (++) to tin, present as tin (stannous) fluoride in toothpaste, observed in a patient with angioedema-like swelling of the lips and aphthous stomatitis.

SUNSCREENS

Recently, two independent research groups demonstrated that sunscreens and cosmetics containing the UV-filter octocrylene always contain unsubstituted benzophenone,[25–26] the levels of which further increase with time ('aging of the product') and exposure to elevated temperatures (eg when stored in a heated car).[25] Unsubstituted benzophenone is the precursor and degradation product of octocrylene and is chemically very similar to the non-steroidal, anti-inflammatory drug ketoprofen. This explains why subjects photo-sensitised to ketoprofen almost invariably develop (severe) photo-ACD from products containing octocrylene (see Figure 2). Commercialised (too pure) octocrylene patch-test materials, unlike samples obtained from the cosmetic companies, often remain false-negative when photo-patch tested.[26] Interestingly, benzophenones are also used in plastics (eg swimming goggles) and inks (eg magazines),[27] which, together with UV-exposure, may result in (severe) photo-ACD with a peculiar skin distribution.

A recent study from Portugal indicated that the 'newer' UV-filters – often with larger molecules and more photostable – might be less problematic,[28] although some of them (eg diethylamino hydroxybenzoyl hexyl benzoic acid/benzoate)[29] are effectively capable of provoking photo-ACD. In addition to UV-filters, UV-absorbing plant extracts, for example *Scutellaria baicalensis*[30] may also be involved.

NAIL COSMETICS

Tosylamide/formaldehyde resin, the classic nail varnish allergen, has been largely replaced by copolymers based on phthalic anhydride and adipic acid,[31] which, although not commercially available, can be patch-tested at 1% in petrolatum. Alternatively, semi-open tests can be performed with nail varnishes containing them. With tosylamide/epoxy resin as the allergen,[2] epoxy resin from the baseline series may show a (strong) positive reaction (personal observation).

Apart from UV- or LED-polymerised methacrylate-based nail gels – known to be problematic – so-called 'hybrid' nail lacquers have gained popularity. These contain HEMA and even bisphenol A-glycidyl methacrylate (Bis-GMA), which are much easier in use as they polymerise upon exposure to sunlight.[33]

Recently, a Korean study drew attention to the potential presence of chromium and also nickel and cobalt in so-called 'nail tips and stickers'.[34] This appears to be a new fashion promoted on some social media networks and can be compared to the hype around epoxy resin-based adhesives for all kinds of hobbyist activity[35] (eg the making of jewellery).

FRAGRANCES AND ESSENTIAL OILS

Fragrances can provoke atypical clinical pictures such as pustular ACD, *lupus tumidus* (personal observation), morphea-like dermatitis,[36] or even a '*leonine facies*'[37] and may contribute to (the therapy-resistance of) rosacea.[38] Some authors claim that fragrances, among other sensitisers, also play a role in the pathophysiology of frontal fibrosing alopecia (FFA)[39] and related skin disorders that lead to 'dermal macular hyperpigmentation' and even in fibromyalgia.[40] Fragrances are also remarkably present in children's toys, pharmaceutical topicals and medical devices. For instance, linalyl acetate, related to linalool, can be found in antiseptics[41] for human and veterinary use.

Figure 2: Severe photo-allergic contact dermatitis (ACD) provoked by benzophenone residues in octocrylene-containing sunscreens, shown in a patient previously photosensitised to ketoprofen (A). The patient also reacted with strong photo-ACD to magazine inks containing benzophenones (B) (Photo courtesy of Prof A Goossens).

Both limonene ('citrus') and linalool ('lavender') are, like other terpenes, present in most essential oils, often (erroneously) regarded as less problematic. Such oils are used in home remedies, but also as aromatherapy and in electronic diffusers (eg to alleviate asthma).[42] They may provoke direct, airborne and (by inhalation) systemic ACD, the latter potentially mimicking atopic dermatitis (AD).

Plant-based fragrances include *Melaleuca alternifolia* (tea tree oil),[43] *Boswellia carterii* ('frankincense'),[44] *Rosa Damascena*,[45] *Gaultheria procumbens*[46] ('wintergreen') and *Thymus vulgaris* (thyme) essential oil.[47] Thyme oil, together with many other fragrances (eg limonene, linalool, citronellal, geraniol, hydroxycitronellal, alpha-isomethylionone, benzyl salicylate and hexyl cinnamal) are potentially present in sanitary napkins and tampons.[48]

Nigella sativa (black seed/black cumin/'the herb from heaven') oil, applied topically or taken orally, may provoke severe ACD and even a drug reaction with eosinophils and systemic symptoms (DRESS).[49] Its main component thymoquinone cross-reacts with the chemical tert-butylhydroquinone (t-BHQ) and this may therefore serve as a marker.

Limonene hydroperoxides are potentially present in D-limonene containing (medical) 'colophonium-free' or 'hypo-allergenic' adhesives.[51]

Several authors advise patch-testing of not only fragrance 'screeners' (mixes in the baseline series), but also individual fragrance chemicals (at higher concentration, as in a 'fragrance series')[52] and essential oils (ylang-ylang, lemongrass, jasmine absolute, sandalwood, clove and neroli oil).[53] The products used should always be tested. Alternatively, if all tests remain negative, one can simply try using fragrance-free products for a period.

HAIR DYES AND BLEACHES

Paraphenylene diamine (PPD) and related substances in hair dyes may also provoke livedoid ACD[54] and, rarely, anaphylactoid/anaphylactic reactions. Newer, powder-based hair dyes (eg indigo)[55] are also potential sensitisers.

Persulfates, used to bleach hair, remain important causes of both delayed and immediate-type hypersensitivity, sometimes combined in one patient (personal observation); asthmatic reactions may occur in hairdressers. Less well-known sensitisation sources are detergents for hot tubs and swimming pools.[56] These contain, for example, potassium peroxymonosulfate, potentially resulting in a difficult-to-manage nummular dermatitis. Such chemicals are also used in cleansers for dental prostheses (cheilitis), antiseptics and paints.

PRESERVATIVES AND BIOCIDES

In the European Union, methylisothiazolinone (MI) and its mixture with methylchloroisothiazolinone (MCI/MI) have been banned in leave-on cosmetics and restricted to a maximum concentration of 15 parts per million in rinse-off cosmetics. Nevertheless, like formaldehyde, they may still be present illegally in some cosmetics and in non-human cosmetics (eg dog shampoos), and other consumer products. Water-based paints, including glues, iron waters[57] and detergents – the latter often also containing benzisothiazolinone (BIT) – are causes of direct, airborne and systemic ACD, sometimes clinically and/or histologically mimicking other skin diseases, such as AD, angioedema,[58] lupus erythematosus and photodermatoses.[59] Isothiazolinones may also occur in flower food[60] and, more worrisome, in nitrile protective gloves.[61] In both cases they are responsible for (occupational) hand dermatitis, and in children's toys such as (home-made) 'slime', leading to (dyshidrotic) hand eczema.[62] BIT has been found (illegally) in hand soaps and (increasingly) in household detergents.[63] This possibly explains the recent increase of reactions to BIT. A related chemical butyl-benzisothiazolinone (BBIT) has been identified as a newly used industrial biocide in cooling fluids.[64] Octylisothiazolinone (OIT), which cross-reacts with MI, has been frequently confirmed as a preservative in leather (shoes, gloves, belts and sofas).[65] MCI/MI and BIT can also be present in these consumer items. In Antwerp, a male patient was observed with a band-like eczema affecting his waist which was attributed to the his wearing a leather belt. The diagnosis could be established only because of a new patch-test preparation, MCI/MI 0.215% aqueous solution, which seems to be more performant than MI 0.2% aqueous solution and MCI/MI 0.02% aqueous solution. The cosmetic industry has meanwhile replaced isothiazolinones with other preservative systems, sometimes leading to a revival of 'old' cosmetic sensitisers, for example chlorphenesine.[66]

Formaldehyde and releasers are sometimes hidden in cosmetics and are capable of provoking atypical clinical ACD pictures.[67] Although formaldehyde 2% in water is a good screener, including for formaldehyde releasers, patch-testing the releasers bronopol and diazolidinyl urea separately is recommended.

Methyldibromo glutaronitrile (MDBGN) is forbidden in cosmetics but is likely still present in other products[68] including medical devices.

Iodopropinyl butylcarbamate may be found in cosmetics[69] (eg colour shampoos) and detergents.

Sorbic acid/potassium sorbate and benzoic acid/sodium benzoate are used increasingly in cosmetics, pharmaceuticals and medical devices[70] (see below).

TEXTILES, PLASTICS AND TATTOOS

Textile colourants are usually screened for by testing the textile dye mix (TDM) 6.6% pet, but due to the presence of Disperse Orange 3 in it, many (strong) co-reactions occur to PPD, which is why the test preparation has been modified.[71] Currently, there is ongoing discussion whether TDM 7.0% in petrolatum (including Disperse Blue 106 and 124 both at 1%) or TDM 5.6% in petrolatum (including both blue azo-dyes at 0.3%) should be tested.

Other colourants that have attracted attention, albeit not in textiles, are both Solvent Orange (n°60) and Red (n°179) in plastics and Yellow (n°33 in Argan oil and n°14 in plastics).[72]

In addition to dyes, other chemicals such as sulfites, fragrances/terpenes, formaldehyde-based resins, isothiazolinones and other biocides (eg chlorophenols) may also be present in textiles.[73] Arylamines and dinitrochlorobenzene[74] may even be present.

An extensive overview of potential contact sensitisers in tattoos and permanent make-up was recently published.[75]

GLOVES

Rubber accelerators are the most common culprits found in rubber gloves, responsible for (occupational) hand dermatitis.

Figure 3: (A) a patient with allergic contact dermatitis (ACD) of the eyelids caused by polyaminopropyl biguanide (PAPB), detected by a patch test with polyhexamethylene biguanide (PHMB); (B) another patient with perilesional ACD from PAPB in a wound-care product, equally detected by a patch test to PHMB.

Thiuram mix from the baseline series may sometimes remain falsely negative or react very late (eg on day 7), and there is an interest to separately patch-test tetramethylthiuram monosulfide (TMTM) (1% in petrolatum) so as not to miss ACD from thiurams/carbamates (eg in nitrile gloves).[76] The frequency of ACD has significantly increased in healthcare workers since the transition from latex to synthetic rubber gloves. In this case 1,3-diphenylguanidine is identified as the most frequently implicated allergen. It can be tested at 1% in petrolatum and as part of carba-mix (3% in petrolatum), but it must be remembered that both preparations sometimes result in irritant patch-test reactions.[77] Isothiazolinones (MI and BIT) and, possibly sulfites,[78] may also be ACD culprits in (rubber) gloves.

FOOT AND SPORTSWEAR

In addition to the classic allergens such as chromium and cobalt in leather, colophonium and p-tert-butylphenol formaldehyde resin in glues, and rubber components in sport shoes and insoles (eg mercapto-derivatives), there are many examples of new sensitisers:

- Octylisothiazolinone, may also be present in compression stockings, rubber and polyurethane boots.[79]

- 2-(thiocyanomethylthio) benzothiazole, an allergen in leather, occasionally co-reacting with mercaptobenzothiazole).[80]
- Dibutyl fumarate and dibutyl maleate, being very similar to dimethyl fumarate (forbidden in the European Union), in working shoes.[81]
- Dimethylthiocarbamyl benzothiazole sulfide (DMTBS), related to thiurams/carbamates, responsible for a mini-epidemic of (canvas) shoe dermatitis in Belgium and the Netherlands.[82]
- Acetophenone azine, the US Allergen of the Year 2021,[83] is an important sensitiser in shin guards, sport's shoes (including trainers and ski boots) and sandals containing the foam-elastomer ethyl vinyl acetate (EVA). A related acetophenone, resacetophenone, is a skin sensitiser in topical antifungals.[84]

ANTISEPTICS AND DISINFECTANTS

The COVID-19 pandemic resulted in an increase in the use of antiseptics and disinfectants, often containing biguanides. These substances included chlorhexidine digluconate, polyhexamethylene biguanide (PHMB), and/or quaternary ammonium salts (QAC) such as benzalkoniumchloride and didecyldimethyl ammoniumchloride.

In France, a particular antiseptic containing chlorhexidine, benzylalcohol and benzalkoniumchloride caused ACD in many patients, some of whom sensitised to all three components.[85] In Switzerland, a case series of ACD from the QAC benzoxoniumchloride,[86] and in the United States a series of patients with irritant CD from QACs were described ('desktop dermatitis'), due their presence in wipes and sprays to clean personal spaces in office environments.[87]

Polyaminopropylbiguanide (PAPB, commercialised at 2.5% aqueous solution), strongly related to PHMB or polyhexanide, is frequently present in make-up removers, causing facial and eyelid dermatitis[88] (see Figure 3). PHMB is also used in wound-care products, responsible for perilesional ACD and delayed wound healing.

German researchers recently pointed out that polyvinylpyrrolidone-iodine should preferably be tested as a 2% aqueous solution as higher concentrations often overestimate contact allergy from this compound.[89] In case of doubt a repeated open application test (ROAT; twice daily for a minimum of 10 days)[90] should be performed.

MEDICAL DEVICES

Many topicals are marketed today as 'medical devices', thereby bypassing the Cosmetics and Pharmaceutical Regulations. They may contain potent (eg resins)[91] or weak (eg sorbic acid/sorbate) sensitisers causing reactions because they are often applied to compromised skin.

Sorbic acid, often present in wound-care products, commercialised as 2% in petrolatum, may need to be patch-tested as 2% in ethanol.[70]

Glucose sensors and insulin infusion sets (insulin pumps) used by many diabetes patients world-wide and complicating management of their diabetes are the most problematic.

Initially, isobornyl acrylate (IBOA) which often cross-reacts with sesquiterpene lactones[92] was identified as the main culprit in the FreeStyle® glucose sensor; however, it has been replaced in newer FreeStyle® sensors. This acrylate can still be present in other sensors (eg Enlite®, Dexcom® (low amounts) and Guardian®) and insulin infusion sets such as Omnipod®, the latter brand also containing dipropylene glycol diacrylate and related acrylates.[93] IBOA was also found in blood pressure cuffs[94] and a new sensitiser, 4-acryloylmorpholine (ACMO), has been found in smart phones and watches.[95] Other culprit acrylates have been identified, most notably 2,2'-methylenebis(6-tert-butyl-4-methylphenol) monoacrylate (MBPA),[96] a larger molecule which penetrates the skin with more difficulty. Therefore MBPA requires higher patch-test concentrations (>0.1% in petrolatum, eg 0.3, 0.5, 1.0 or even 1.5% in petrolatum). Cyanoacrylates, which rapidly polymerise and remain a relatively rare cause of ACD, can be present in both surgical glues and in nail and eyelash glue. Recent experiences have illustrated that individual molecules easily cross-react, that is, octyl-, butyl- and ethyl cyanoacrylate (personal observation).

Other adhesive components such as isocyanates (mainly MDI for which MDA and possibly also TDI may serve as markers),[97] colophonium and modified colophonium (not always cross-reacting with the former, and present in hydrocolloid dressings)[98] have been shown to contribute to ACD from diabetic and other devices, and modern wound dressings.

Many other potential culprits – beyond the scope of this review – have been suspected, among which is benzoyl peroxide;[99] however, confirmatory analyses are still lacking.

Silicones, although present as large molecules, may occasionally cause ACD and should therefore be patch-tested. Additives, degradation products or impurities are probably the real sensitisers.

Recent reports suggest that metals (eg platinum, also found as a culprit in a glucose sensor),[100] acrylates (eg HEMA) and UV-absorbers (eg drometrizole, also found in cosmetics, sanitary napkins, dental materials, rubbers and plastics) have been implicated in ACD from medical devices.[101]

METALS

Nickel may cause both delayed and immediate reactions (eg angioedema).[102] Owing to its presence in dental materials, nickel is sometimes responsible for perioral eczema without any mucosal lesions.[103]

Aluminium (Alu; US Allergen of the Year 2022), the major culprit in vaccine-related subcutaneous granulomas,[104] is also found in deodorants, sunscreens, toothpastes and food. Alu should be patch-tested as Alu chloride hexahydrate 2% in petrolatum in children <8 years of age and as 10% in petrolatum in all other subjects – ideally with readings up to day 7.[105]

Tin (stannous) (causing cheilitis and stomatitis) can be tested at 50% in petrolatum (see above) and/or as tin oxalate 1% pet.

Titanium remains a rare but possibly underestimated contact sensitiser and debate is still ongoing about which test preparation

is most suitable (titanium oxalate, titanium nitride or other salts); irritant reactions may occasionally occur.[106]

Gold is a frequent contact sensitiser, yet its relevance remains difficult to trace. Recently, in Antwerp two patients were observed who developed systemic AD from gold contained in Embogold®, an intravenous solution used for vascular embolisation (personal observation).

Iron, present in perioperatively used instruments, and tested as iron sulphate 5% in petrolatum, with readings up to day 7, might be a potential explanation for some cases of prosthesis failure.[107]

CONFLICT OF INTEREST
Olivier Aerts is an investigator, consultant and/or speaker for Leo Pharma, Abbvie, L'Oréal/La Roche Posay and Bioderma/NAOS. The other authors have no conflicts to declare.

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