

Occupational Contact Dermatitis in North American Print Machine Operators Referred for Patch Testing: Retrospective Analysis of Cross-Sectional Data From the North American Contact Dermatitis Group 1998 to 2014

Erin M. Warshaw, MD, MS,*† Solveig L. Hagen, BA,* Donald V. Belsito, MD,‡ Joel G. DeKoven, MD,§ Howard I. Maibach, MD,|| C.G. Toby Mathias, MD,¶ Kathryn A. Zug, MD,# Denis Sasseville, MD,** Matthew J. Zirwas, MD,†† Joseph F. Fowler, Jr, MD,‡‡ Anthony F. Fransway, MD,§§ Vincent A. DeLeo, MD,|||| James G. Marks, Jr, MD,¶¶ Melanie D. Pratt, MD,## and James S. Taylor, MD***

Background: Little is known about the epidemiology of contact dermatitis (CD) in print machine operators (PMOs).

Objective: The aims of this study were to estimate the prevalence of CD and characterize clinically relevant and occupationally related allergens among PMOs undergoing patch testing.

Methods: This was a retrospective cross-sectional analysis of the North American Contact Dermatitis Group data from 1998 to 2014.

Results: Of 39,332 patch-tested patients, 132 (0.3%) were PMOs. Among PMOs, most were male (75.0%) and white (92.4%). The majority were printing press operators (85.6%). The most frequent sites of dermatitis were hands (63.6%), arms (29.5%), and face/scalp (24.2%). More than half had an occupationally related skin condition (56.1%). Final diagnoses were most commonly allergic CD (58.3%) and irritant CD (33.3%). Cobalt (20.8%), carba mix (12.5%), thiuram mix (8.3%), and formaldehyde (8.3%) were the most frequent occupationally related allergens. The top allergen sources included inks (22.9%), gloves (20.8%), and coatings/dye/copy/photographic chemicals (14.6%).

Conclusions: Allergic CD, irritant CD, and involvement of exposed body areas were common among PMOs. Common allergens included rubber accelerators, metals, and preservatives.

More than 13 million US laborers contact chemicals in their work environment.¹ Exposure to workplace chemicals and substances may lead to contact dermatitis (CD), the most common occupationally related skin disease in the United States and Canada.^{1,2} Employment in the printing industry is a well-known

risk factor for development of occupational skin diseases and disorders (OSDs). Data published from the United Kingdom's OSD surveillance scheme, EPIDERM, demonstrated an annual incidence rate of approximately 86 cases of dermatitis per 1,000,000 printers.³ Livesley et al⁴ surveyed 1189 print workers in the United Kingdom and found that 490 (42%) reported a skin complaint while so employed. Of this group, 58% were ultimately diagnosed with an OSD upon clinical examination.⁴ Printing is among the largest

From the *HMC Parkside Occupational and Contact Dermatitis Clinic and Department of Dermatology, Minneapolis Veterans Affairs Medical Center; and †Department of Dermatology, University of Minnesota Medical School, Minneapolis; ‡Department of Dermatology, Columbia University, New York, NY; §Division of Dermatology, Sunnybrook Health Sciences Centre, University of Toronto, Ontario, Canada; ||Department of Dermatology, University of California San Francisco; ¶Department of Dermatology, University of Cincinnati, OH; #Dartmouth-Hitchcock Medical Center, Lebanon, NH; **Division of Dermatology, Royal Victoria Hospital, McGill University, Montreal, Quebec, Canada; ††Ohio State University, Columbus; ‡‡University of Louisville, KY; §§Associates in Dermatology, Fort Myers, FL; ||||Department of Dermatology, Keck School of Medicine at University of Southern California, Los Angeles; ¶¶Department of Dermatology, Pennsylvania State University, State College; ##Division of Dermatology, University of Ottawa, Ontario, Canada; and ***Department of Dermatology, Cleveland Clinic, OH.

Address reprint requests to Solveig L. Hagen, BA, Minneapolis VA Medical Center, Dept 111K 1 Veterans Dr, Minneapolis, MN 55417. E-mail: erinmwarshaw@gmail.com.

This material is based on work supported in part by the Minneapolis Veterans Affairs Medical Center. There are no other sources of funding for this work.

The authors have no funding or conflicts to declare.

The contents of this publication do not represent the views of the Department of Veterans Affairs or the US Government.

DOI: 10.1097/DER.0000000000000269

© 2017 American Contact Dermatitis Society. All Rights Reserved.

manufacturing industries in the United States and Canada. Known skin irritants in the printing industry include inks, alcohols, greases, waxes, and developers, and contact allergens include metals, preservatives, and adhesives.

Workers in the printing industry comprise an important segment of North American economies. In 2011, there were an estimated 81,600 workers in the Canadian printing industry and 6149 printing companies.⁵ There were twice as many print machine operators (PMOs) in the United States in 2015 (168,330).⁶

Printing Technology

Print machine operators work in a variety of environments and are responsible for setting up and operating digital, letterpress, lithographic, flexographic, gravure, or other printing machines, including short-run offset printing presses (Table 1).⁷ The printing process involves 4 elements: an image carrier, image transfer method, ink, and printing substrate. Letterpress is a form of relief printing, whereby raised type is pressed against paper to create a printed impression. Letterpress is used for stationary, invitations, fine books, and posters. The modern form of letterpress, flexography, utilizes flexible rubber plates to print on curved surfaces. Many labels, beverage containers, plastic bags, wrappers, and adhesives tapes are printed with flexography machines. In contrast to the raised images used in letterpress and flexography, gravure printing utilizes an etched plate, wherein the plate depressions are filled with ink. Offset printing also uses plates (typically aluminum) to transfer an image. The nonprinting area of the plate is coated with an aqueous fountain solution; the printing area is then rolled with hydrophobic ink. The image is transferred from the plate to a rubber “blanket” and then rolled onto printing stock. This method is called offset because the ink is not transferred directly to paper. In lithography printing, an image is made from a polymer coating and applied to an aluminum plate. The image can either be printed directly from the plate or offset (transferred to rubber and then printed). Offset lithography is one of the most common forms of printing and is used to produce newspapers, magazines, brochures, and books. Digital printing does not utilize plates. The process of silkscreen printing involves the use of a mesh stencil, through which ink is squeezed. This technique is useful for printing labels or images on plastic, fabric, glass, or metal.

Printing Inks

Printing inks contain 4 basic components: pigments (add color), resins (bind ink ingredients), solvents (keep the ink liquid when transferred between surfaces), and additives (alter the ink's physical properties). Inks are manufactured in a 2-step process. First, a clear liquid varnish is made from a combination of resins, solvents, and additives. Pigment is mixed into the varnish to create evenly colored ink. Letterpress and offset inks typically contain an oil base such as linseed and dry slowly by penetration and solvent evaporation. Unlike other inks, digital printing ink forms a thin layer on the surface of the printing substrate and does not

TABLE 1. Printing Technology

Printing form Method	Screen				
	Letterpress	Flexography	Gravure	Offset	Lithography
	Relief Raised type is set on metal plate and pressed against paper	Relief Raised type is set on flexible rubber plates to print on curved surfaces	Engraved cylinder Ink is applied to the depressions of an etched metal plate	Multiple Inked image transferred (“offset”) from plate to rubber blanket, then to printing substrate	Flat Image created from polymer coating and applied to metal plate
Final product	Fine paper goods, stationery, books, posters	Paper, boards, polymers, plastic, adhesive tape	Long print runs (magazines, packaging, fabric, wallpaper), polymers, laminates	Books, newspapers, magazines	Paper, newspapers, magazines, brochures, books
					Stencil and mesh Ink is squeezed through mesh stencil
					Digital Inklets recreate digital image via precise placement of tiny ink droplets
					All, 3D printing Fabric, tiles, glass, metal, uneven surfaces

permeate. In general, inks may be further fixed using a fuser fluid with heat (toner) or ultraviolet (UV) curing process (ink). In contrast to conventional inks, UV inks are generally solvent-free. These inks contain multifunctional acrylic monomers (pentaerythritol triacrylate [PETA], trimethylolpropane triacrylate, hexanediol diacrylate), unsaturated acrylated oligomers (acrylated polyesters, epoxy, alkyds, or urethanes), and a photoinitiator (benzophenone).⁸

To date, there have been numerous case reports and case series published on the topic of CD in PMOs; however, most analyzed small cohorts and originated outside North America.^{4,8–25} The purpose of this analysis was to describe occupationally related CD in patch-tested PMOs utilizing 17 years of data from the North American Contact Dermatitis Group (NACDG) and characterize responsible allergens and irritants, as well as their occupational sources.

METHODS

NACDG Database

The NACDG patch tested 39,332 patients to a baseline series of 50 to 70 allergens between July 1, 1998, and December 31, 2014. Patch-testing data were reported over consecutive cycles, approximately 2 years in length (eg, 2013–2014, etc). The subjects reported herein were included in a recently published (submitted) analysis of production workers as a whole; however, this study did not examine trends within specific occupational subgroups, such as PMOs.²⁶ Methods of patch testing, reaction relevance, and final diagnoses were determined according to published methods.²⁷ Demographic information (age, sex, race), occupation, site of dermatitis (up to 3), final diagnosis (up to 3), and patch-testing results were collected at the time of patch testing. An expert in occupational classification determined patient occupation and industry using the 3-digit codes published by the 1990 US Department of Commerce Census Industrial and Occupational Classification Codes.²⁸ Site codes and final diagnoses were linked to individual patients but not specific allergens. For each positive reaction, the clinical relevance (“definite,” “probable,” “possible,” “past,” “unknown,” “not applicable,” or “not tested”) and occupational relatedness were recorded.²⁷ Beginning in 1998, 3-digit source codes were determined for positive NACDG screening series reactions. From 1996 on, source and occupational relatedness were also assigned to other relevant allergens and irritants not included in the NACDG screening series. Clinically relevant non-NACDG irritant and allergen sources and their occupational relatedness were associated to individual subjects, but not to specific antigens.

STUDY DESIGN

Analysis of the deidentified data was approved by the Subcommittee on Human Studies at the Minneapolis Veterans Affairs Medical Center. This descriptive analysis focused on subjects with 3-digit occupational codes corresponding to the occupational subgroup, “print machine operators” (occupational codes 734–737). Only positive patch-test reactions determined to be both of current

clinical significance and related to occupation were included in the final analyses. At a central location, all data were manually entered into a computerized database. Data were checked for quality assurance at the time of collection (Access 2003; Microsoft Corporation, Redmond, WA).

RESULTS

Demographics

Between July 1, 1998, and December 31, 2014, 39,332 patients were patch tested by the NACDG. Of these, 132 (0.3%) were PMOs. The overwhelming majority of patch-tested PMOs were printing press operators ($n = 113$, 85.6%) (Table 2). A majority of PMOs were male (75.0%), older than 40 years (65.2%), and white (92.4%) (Table 3). More than half of the subjects were found to have an occupationally related skin condition (56.1%). A history of eczema was relatively uncommon in this study population (7.6%). Hands (63.6%) were the most common site of involvement, followed by arms (29.5%) and face/scalp (24.2%). Allergic contact dermatitis (ACD) was the most frequent final diagnosis (58.3%), followed by irritant CD (ICD) (33.3%) and other dermatitis (12.9%).

Frequencies of Occupationally Related NACDG Allergens

Table 4 outlines the frequencies of occupationally related NACDG screening allergens and the top sources of these in PMOs. Cobalt chloride (20.8%), carba mix (12.5%), thiuram mix (8.3%), and formaldehyde 1% (8.3%) were the most common occupationally related allergens in PMOs.

NACDG Allergen Sources

The top sources of occupationally related NACDG allergens are summarized in Table 5. Overall, chemicals and chemical products were primary sources of occupationally related allergens (43.8%). Not surprisingly, inks were the no. 1 source of allergens in PMOs (22.9%). Other common sources of allergens included gloves (20.8%) and coatings, dyes, and photographic and copy chemicals (14.6%).

Sources of Occupationally Related Non-NACDG Allergens

There were 22 occupationally related non-NACDG allergen sources identified in PMOs (Table 6). Chemical and chemical products were the most common sources of non-NACDG

TABLE 2. PMO Occupational Subgroups

PMO Subgroups ($n = 132$)	n (%)
Printing press operators	113 (85.6)
Photoengravers and lithographers	8 (6.1)
Miscellaneous printing operators	7 (5.3)
Typesetter and compositors	4 (3.0)

TABLE 3. Demographics of PMOs Referred for Patch Testing

Demographic	PMOs (n = 132), n (%)
Male	99 (75.0)
Age >40 y	86 (65.2)
White	122 (92.4)
Occupationally related skin condition	74 (56.1)
Atopy	
Hay fever	13 (9.8)
Eczema	10 (7.6)
Asthma	10 (7.6)
Site*	
Hand	84 (63.6)
Arm	39 (29.5)
Face, scalp†	32 (24.2)
Generalized	29 (22.0)
Trunk	13 (9.8)
Leg	10 (7.6)
Foot	10 (7.6)
Neck	5 (3.8)
Most exposed areas	2 (1.5)
Anal/genital	2 (1.5)
Other	1 (0.8)
Only under clothing	1 (0.8)
Final diagnosis‡	
ACD	77 (58.3)
ICD	44 (33.3)
Other dermatitis	17 (12.9)
Psoriasis	11 (8.3)
Other dermatoses	5 (3.8)
Atopic dermatitis	5 (3.8)
Nummular eczema	5 (3.8)
Contact urticaria	2 (1.5)
Pompholyx	1 (0.8)

*Total percentage may exceed 100% because up to 3 sites could be identified for each patient.

†Including face, lips, nose, eyelids, eyes, ears, and scalp.

‡Listed as 1 of 3 final diagnoses; therefore, total percentage may exceed 100%.

allergens (86.4%). Within this category, the most frequent sources included inks (59.1%); coatings, adhesives, dyes, and copy chemicals (13.6%); and photographic chemicals (9.0%).

Sources of Occupationally Related Irritants

In this population, 33.3% of patch-tested PMOs were determined to have ICD. The most commonly identified irritant sources were chemicals and chemical products (85.2%). Among chemical sources, solvents, degreasers, and petroleum distillates (34.8%) were the top sources of occupationally related ICD. Inks (25.9%), followed by coatings/dyes/copy chemicals (1.1%) and photographic chemicals (7.4%), were also frequent sources of irritants in PMOs. Table 7 outlines occupationally related sources of non-NACDG irritants in PMOs.

DISCUSSION

This retrospective analysis of PMOs patch tested by the NACDG over a 17-year period demonstrates several important findings. First, occupationally related skin disease and a final diagnosis of ACD and ICD were common among PMOs. Second, involvement of exposed areas of the body, especially the hands and arms, was frequent. Third, rubber accelerators, metals, and preservatives were commonly identified occupationally related allergens. Fourth, inks, gloves, coatings, dyes, photographic, and copy chemicals were frequent sources of occupationally related allergens. Finally, ICD was diagnosed in approximately one third of PMOs, and solvents, degreasers, and petroleum distillates; inks; coatings; dyes; and copy chemicals were the top irritant sources.

Demographics, Occupational Relevance, Final Diagnosis, and Site of Dermatitis

The higher proportion of males (75.0%) likely reflects known sex differences in the US labor force. In 2015, the US Bureau of Labor and Statistics Current Population Survey reported approximately 80.0% of printing press operators were male.²⁹ Occupational skin diseases and disorders were diagnosed in 56.1% of PMOs. This finding is not unexpected, as we predicted that PMOs are at increased risk of occupationally related dermatitis, given regular exposure to a spectrum of well-known allergens and irritants including metals, inks, adhesives, coatings, and rubber. A previous study of Canadian printing workers with eczematous dermatitis demonstrated similar prevalence of ACD (67%) and ICD (33%).⁸ In our analysis, the frequency of ICD is likely underestimated because patients referred for patch testing were suspected of having ACD.

It was not surprising that exposed areas of the body (hands, arms, face, and scalp) were the most commonly involved sites of dermatitis. Printing workers contact many irritating and sensitizing solvents, inks, and other chemicals with their hands and arms. Facial involvement was also common and may be secondary to the transfer of sensitizing chemicals from the hands to the face or airborne exposures. There have been reports of facial dermatitis in high-speed print workers.³⁰ Printing inks form microdroplets in the air, a phenomenon known as “ink fly,” which is thought to cause facial dermatitis in some PMOs.^{24,30} Importantly, spread to covered areas is not uncommon.

Allergens and Their Sources

Rubber Accelerators

The rubber accelerators, carba mix and thiuram mix, were the number 2 and number 3 most common allergens in PMOs. Allergic contact dermatitis to these chemicals was associated with exposure to rubber gloves worn in the workplace. Rubber accelerators are added to gloves during the manufacturing process to hasten vulcanization; however, trace amounts of these chemicals remain on the finished products and are released during use. Thiurams, carbamates, and benzothiazoles are commonly used rubber accelerators. Rubber agents are well-known causes of

TABLE 4. Occupationally Related NACDG Screening Allergens and Sources in PMOs

Antigen	Top Occupationally Related Sources				Total (n = 48), n (%)
	#1	#2	#3	#4	
Cobalt chloride 1% pet	Inks (3)	Miscellaneous machinery (1)	Machinery/vehicles (5)	N/A (1)	10 (20.8)
Carba mix 3% pet	Gloves (6)				6 (12.5)
Thiuram mix 1% pet	Gloves (4)				4 (8.3)
Formaldehyde 1% aq	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)	Adhesives (1)	Moisturizers, lotions, creams (1)	Waterless hand soaps (1)	4 (8.3)
2-Hydroxyethyl methacrylate, 2.0% pet*	Inks (2)	N/A (1)			3 (6.3)
Quaternium-15 2% pet	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)	Inks (1)	Moisturizers, lotions, creams (1)		3 (6.3)
Potassium dichromate 0.25% pet	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)	Inks (1)			2 (4.2)
Ethyl acrylate 0.1% pet	Inks (2)				2 (4.2)
Propylene glycol 30% aq	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)	Solvents, degreases, petroleum distillates (1)			2 (4.2)
Methyl methacrylate 2% pet	Inks (1)				1 (2.1)
Colophony 20% pet	Inks (1)				1 (2.1)
Balsam of Peru 25% pet	Wipes (baby wipes, toilettes, etc) (1)				1 (2.1)
Methylchloroisothiazolinone/methylisothiazolinone 100 ppm aq	Moisturizers, lotions, creams (1)				1 (2.1)
Neomycin sulfate 20% pet	Medications, topical antibiotics (1)				1 (2.1)
Cocamide DEA 0.5% pet†	Pumice stones (1)				1 (2.1)
Glutaral 1% pet	Wipes (baby wipes, toilettes, etc) (1)				1 (2.1)
Bacitracin 20% pet	Medications, topical antibiotics (1)				1 (2.1)
Diazolidinyl urea 1% pet	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)				1 (2.1)
Fragrance mix 8% pet	Wipes (baby wipes, toilettes, etc) (1)				1 (2.1)
Imidazolidinyl urea 2% pet	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)				1 (2.1)
Methyldibromo glutaronitrile/phenoxylethanol 2.0% pet	N/A (1)				1 (2.1)
Chloroxylenol (PCMX) 1% pet	N/A (1)				1 (2.1)

(continued on next page)

TABLE 4. (Continued)

Antigen	Top Occupationally Related Sources				Total (n = 48), n (%)
	#1	#2	#3	#4	
Formaldehyde, 2.0% aq‡	Coatings, adhesives, dyes, photographic and copying chemicals NOS (1)				1 (2.1)
Cocamidopropyl betaine 1% aq†	Pumice stones (1)				1 (2.1)
PG 100%‡	Metalworking fluid, cutting oils (1)				1 (2.1)
Thimerosal 0.1% pet§	Medications, PO or IM, subcutaneous (1)				1 (2.1)

*Tested in only 4 cycles.

†Tested in only 7 cycles.

‡Tested in only 1 cycle.

§Tested in only 2 cycles.

IM indicates intramuscular; NOS, not otherwise specified; N/A not applicable; PO, orally.

OSDs. Worldwide, thiurams are considered the most common rubber contact allergen³¹; however, many manufacturers are shifting to remove thiuram from their gloves.^{31,32} A recent Danish study of CD to rubber accelerators also found that contact allergy to thiuram mix was the most prevalent rubber allergen and was significantly associated with OSD.³³

Metals

Cobalt chloride and potassium dichromate were frequently identified occupationally related allergens in PMOs. Allergic contact dermatitis to these metals was attributed to workplace exposures to inks, coatings, and machinery. Cobalt is a well-known sensitizer and is occasionally added to catalyze the oxidation and drying of inks.^{34–36} The most recent data from the NACDG demonstrated 7.3% of 4231 patch-tested patients reacted to cobalt.²⁷ In Finland, occupational CD to cobalt was observed in printers, mechanics, and toolmakers.³⁶ Kanerva et al¹² reported occupational ACD in a Finnish offset printer caused by cobalt-2-ethylhexoate, a drying agent found in 2 different inks contacted at work. Other drying agents include manganese, lead, zinc, calcium, barium, zirconium, and tin naphthenates.³⁷

Preservatives

Preservatives were common sources of occupationally related ACD in PMOs. Formaldehyde and quaternium-15 accounted for nearly 15% of occupationally related skin allergy in the study population. Many letterpress and offset inks contain resins such as phenol/formaldehyde or alkyl/formaldehyde.⁸ Resins bind ink ingredients to form a film and also help fix inks to printing substrates. Quaternium-15 is a formaldehyde-releasing chemical. In this study, ACD to preservatives was most commonly due to contact with coatings, adhesives, dyes, inks, photographic and copying chemicals, solvents, and personal care products.

Acrylates

Acrylates are plastics derived from acrylic or methacrylic acid and formed by the polymerization of monomers. Allergic contact dermatitis to acrylates, including 2-hydroxyethyl methacrylate (HEMA), ethyl acrylate (EA), and methyl methacrylate (MMA), was commonly observed in our study population. Acrylates are components of many UV-cured inks and printing plates.³⁸ The only 3 acrylates included in the NACDG screening series are HEMA, EA, and MMA. Many printing acrylates are tested with specialty patch-testing series.

Acrylates are well-known causes of occupationally related ACD; the first reported case involved workers in a German printing plant.¹³ Since then, there have been numerous reports of occupational ACD to acrylates in printers.^{10,11,13,15–20,22–25,39,40} Emmett³⁹ described 4 workers in an Ohio factory that produced UV-cured printing inks and subsequently developed ACD of the hands, forearms, trunks, and face after sensitization to PETA and trimethylpropane triacrylate in the manufactured inks. Smith³⁰ reported 2 British flatbed letterpress operators who developed ACD to PETA following sensitization to a new UV-cured ink containing this chemical. Björkner et al¹⁰ described 6 Swedish workers who developed occupational ACD to PETA, trimethylpropane triacrylate, epoxy acrylate, and polyesteracrylate prepolymers while working with UV-curing inks in 4 different printing plants. Inks were responsible for all cases of occupationally related ACD in our analysis.

Solvents

Propylene glycol (PG) is a solvent and was identified as an occupationally related allergen in 4.2% of the study population. Noiles et al²¹ reported a case of occupationally related ACD to PG in a PMO. Propylene glycol was identified in the printing press fountain solution as well as an orange hand-cleaner pumice lotion utilized at work. Some PMOs are responsible for cleaning the

TABLE 5. Occupationally Related NACDG Allergens by Source in PMOs

Source	Top 3 Occupationally Related Antigens			Total (n = 48), n (%) [*]
	#1	#2	#3	
Chemicals and chemical products				21 (43.8)
Inks	Cobalt chloride (3)	2-Hydroxyethyl methacrylate (2)	Ethyl acrylate (2)	11 (22.9)
Coatings/dyes/photographic and copy chemicals NOS	Formaldehyde (1) Quaternium-15 (1) Potassium dichromate (1) Propylene glycol (1) Diazolidinyl urea (1) Imidazolidinyl urea (1)			7 (14.6)
Adhesives	Formaldehyde (1)			1 (2.1)
Solvents, degreasers, petroleum distillates	Propylene glycol (1)			1 (2.1)
Metalworking fluids, cutting oils	Propylene glycol (1)			1 (2.1)
Clothing				10 (20.8)
Gloves	Carba mix (6) Thiuram mix (4)			10 (20.8)
Personal care products				9 (18.8)
Wipes	Balsam of Peru (1) Fragrance mix (1) Glutaral (1)			3 (6.3)
Moisturizers, lotions, creams	MCI/MI (1) Quaternium-15 (1) Formaldehyde (1)			3 (6.3)
Pumice stones	Formaldehyde (1) Cocamidopropyl betaine (1)			2 (4.2)
Waterless hand soaps	Formaldehyde (1)			1 (2.1)
Machinery/vehicles, NOS	Cobalt chloride (1)			1 (2.1)
Medications	Neomycin sulfate (1) Bacitracin (1)	Thimerosal (1)		3 (6.3)
Other	Cobalt chloride (1) 2-Hydroxyethyl methacrylate (1) Methyldibromo glutaronitrile/ phenoxyethanol (1) Chloroxylenol (1)			4 (8.3)

^{*}Percentage is the percent that each category represents of total NACDG allergen sources.

MCI/MI indicates methylchloroisothiazolinone/methylisothiazolinone; NOS, not otherwise specified.

plates following a printing run. Blanket washes containing PG may be used to remove UV and conventional inks from plates.⁸

Irritants

Occupationally related ICD was ultimately diagnosed in 44 subjects (33.3%). Chemicals were the primary source of irritants in PMOs. Sources of workplace irritants included solvents, degreasers, inks, coatings, dyes, and copying chemicals. These findings align with previous reports of ICD in the printing industry.^{8,18}

Limitations

This analysis poses several important limitations. Given its cross-sectional descriptive nature, causal relationships could not be

TABLE 6. Sources of Occupationally Related Non-NACDG Allergens in PMOs

Source	Total (n = 22), n (%)
Chemicals and chemical products	19 (86.4)
Inks	13 (59.1)
Coatings, adhesives, dyes, and copy chemicals	3 (13.6)
Photographic chemicals	2 (9.0)
Aldehyde-related chemicals	1 (4.5)
Personal care products	2 (9.0)
Other	1 (4.5)

TABLE 7. Sources of Occupationally Related Irritants in PMOs

Source	n (%) of Total (n = 27)
Chemicals and chemical products	23 (85.2)
Solvents, degreasers, petroleum distillates	8 (34.8)
Inks	7 (25.9)
Coatings, dyes, and copying chemicals	3 (1.1)
Photographic chemicals	2 (7.4)
Solvents, oils, lubricants, fuels	2 (7.4)
Adhesives, glues, bonding agents	1 (3.7)
Personal care products	1 (3.7)
Other	3 (11.1)

determined. In the future, large prospective studies are needed to better elucidate the development of ACD in PMOs. Furthermore, the study population was composed of patients suspected of having ACD and referred for patch testing. Therefore, the results presented herein may not be extrapolated to other populations of PMOs. The identification of source was limited by the patch-testing dermatologist's knowledge and the available 3-digit source codes. Additional limitations include lack of long-term follow-up and lack of specialty-specific acrylates in the NACDG screening series. Finally, important occupationally related allergens and irritants may have been missed, as the specific names of non-NACDG allergens were not recorded.

CONCLUSIONS

Among PMOs patch tested by the NACDG between 1998 and 2014, occupationally related skin disease and a final diagnosis of ACD and ICD were common. Involvement of exposed body areas (hands, arms, face) was frequently reported. The top occupationally related allergens were rubber accelerators (thiuram mix, carba mix), metals (cobalt chloride, potassium dichromate), preservatives (formaldehyde, quaternium-15), acrylates (HEMA, EA, MMA), and solvents (PG). The top sources of work-related skin allergy were inks, gloves, coatings, dyes, and photographic and copy chemicals. Irritant CD was diagnosed in approximately one third of PMOs and was most commonly attributed to contact with solvents, degreasers, inks, coatings, and dyes.

REFERENCES

1. Skin Exposures and Effects. National Institute for Occupational Safety and Health. Available at: <http://www.cdc.gov/niosh/topics/skin/>. Published 2013. Accessed May 19, 2016.
2. Occupational skin disease—it is more than just a rash. 2012;1–4. Available at: <https://www.pshsa.ca/wp-content/uploads/2013/07/OIFFCAEN0313-Occupational-Skin-Disease-more-than-just-a-rash-English-HR.pdf>. Accessed June 9, 2016.
3. Meyer JD, Chen Y, Holt DL, et al. Occupational contact dermatitis in the UK: a surveillance report from EPIDERM and OPRA. *Occup Med (Lond)* 2000;50(4):265–273.
4. Livesley EJ, Rushton L, English JS, et al. The prevalence of occupational dermatitis in the UK printing industry. *Occup Environ Med* 2002;59:487–492.
5. Printing and related support activities industry profile. Innovation, Science and Economic Development Canada. Available at: https://www.ic.gc.ca/eic/site/026.nsf/eng/h_00077.html. Published 2016. Accessed September 20, 2016.
6. US Department of Labor Statistics. Printing press operators. Occupational employment and wages. Available at: <http://www.bls.gov/oes/current/oes515112.htm#ind>. Published 2015.
7. 2010 SOC Definitions. US Department of Labor Statistics. 2010;163–185. Available at: http://www.bls.gov/soc/soc_2010_definitions.pdf. Accessed August 4, 2016.
8. Nethercott JR, Nosal R. Contact dermatitis in printing tradesmen. *Contact Dermatitis* 1986;14(5):280–287.
9. Anderson SE, Tapp L, Durgam S, et al. The identification of a sensitizing component used in the manufacturing of an ink ribbon. *J Immunotoxicol* 2012;9(2):193–200.
10. Björkner B, Dahlquist I, Fregert S. Allergic contact dermatitis from acrylates in ultraviolet curing inks. *Contact Dermatitis* 1980;6(6):405–409.
11. Higgins E, Collins P. Urticarial allergic contact dermatitis caused by UV-cured printing ink. *Contact Dermatitis* 2012;66(6):340–341.
12. Kanerva L, Jolanki R, Estlander T. Offset printer's occupational allergic contact dermatitis caused by cobalt-2-ethylhexoate. *Contact Dermatitis* 1996;34(1):67–68.
13. Magnusson B, Mobacken H. Allergic contact dermatitis from acrylate printing plates in a printing plant. *Berufsdermatosen* 1972;20(3):138–142.
14. Malten KE. Letterflex photoprepolymer sensitization in newspaper printers due to penta erythritol tetrakis 3 mercaptopropionate and 3 mercaptopropionic acid. *Contact Dermatitis* 1977;3(5):257–262.
15. Malten KE. Contact sensitization to Letterflex urethane photoprepolymer mixture used in printing. *Contact Dermatitis* 1977;3(3):115–121.
16. Malten KE, Bende WJ. 2-Hydroxy- ethyl-methacrylate and di- and tetraethylene glycol dimethacrylate: contact sensitizers in a photoprepolymer printing plate procedure. *Contact Dermatitis* 1979;5(4):214–220.
17. Morgan VA, Fewings JM. 1,6-Hexanediol diacrylate: a rapid and potent sensitizer in the printing industry. *Australas J Dermatol* 2000;41(3):190–192.
18. Nethercott JR. Skin problems associated with multifunctional acrylic monomers in ultraviolet curing inks. *Br J Dermatol* 1978;98(5):541–552.
19. Nethercott JR. Allergic contact dermatitis due to an epoxy acrylate. *Br J Dermatol* 1981;104(6):697–703.
20. Nethercott JR, Jakubovic HR, Pilger C, et al. Allergic contact dermatitis due to urethane acrylate in ultraviolet cured inks. *Br J Ind Med* 1983;40(3):241–250.
21. Noiles K, Kudla I, DeKoven J. Propylene glycol dermatitis in the printing industry: the fundamental role of a workplace visit. *Dermatitis* 2010;21(1):E1–E4.
22. Pedersen NB, Senning A, Nielsen AO. Different sensitising acrylic monomers in Napp printing plate. *Contact Dermatitis* 1983;9(6):459–464.
23. Wahlberg JE. Contact sensitivity to NAPP printing plates secondary to a relapsing hand dermatitis. *Contact Dermatitis* 1983;9(3):239.
24. Whitfeld M, Freeman S. Allergic contact dermatitis to ultra violet cured inks. *Australas J Dermatol* 1991;32(2):65–68.
25. Widström L. Contact allergy to acrylate monomer in a printing plate. *Contact Dermatitis* 1982;8(1):68–69.
26. Warshaw EM, Hagen SA, DeKoven J, et al. Occupational contact dermatitis in North American production workers referred for patch testing:

- retrospective analysis of cross-sectional data from the North American Contact Dermatitis Group 1998 to 2014. *Dermatitis* In press.
27. Warshaw EM, Maibach HI, Taylor JS, et al. North American Contact Dermatitis Group patch test results: 2011–2012. *Dermatitis* 2015;26(1):49–59.
28. US Bureau of the Census. *1990 Census of Population and Housing, Alphabetical Index of Industries and Occupations*. Washington, DC: U.S. Dept. of Commerce, Economics and Statistics Administration, Bureau of the Census; 1992.
29. Labor Force Statistics from the Current Population Survey. Household Data Annual Averages. Table 11b. Employed persons by detailed occupation and age. Bureau of Labor Statistics Population Survey. Available at: <http://www.bls.gov/cps/cpsaat11b.htm>. Published 2015. Accessed August 4, 2016.
30. Smith W. Allergic dermatitis due to a triacrylate in ultraviolet cured inks. *Contact Dermatitis* 1977;3(6):312–314.
31. Geier J, Lessmann H, Mahler V, et al. Occupational contact allergy caused by rubber gloves—nothing has changed. *Contact Dermatitis* 2012;67(3):149–156.
32. Pontén A, Hamnerius N, Bruze M, et al. Occupational allergic contact dermatitis caused by sterile non-latex protective gloves: clinical investigation and chemical analyses. *Contact Dermatitis* 2013;68(2):103–110.
33. Schwensen JF, Menné T, Johansen JD, et al. Contact allergy to rubber accelerators remains prevalent: retrospective results from a tertiary clinic suggesting an association with facial dermatitis. *J Eur Acad Dermatol Venereol* 2016;30(10):1768–1773.
34. Jolanki R, Tarvainen K, Tatar T, et al. Occupational dermatoses from exposure to epoxy resin compounds in a ski factory. *Contact Dermatitis* 1996;34(6):390–396.
35. Fowler JF Jr. Cobalt. *Dermatitis* 2016;27(1):3–8.
36. Kanerva L, Jolanki R, Estlander T, et al. Incidence rates of occupational allergic contact dermatitis caused by metals. *Am J Contact Dermat* 2000;11(3):155–160.
37. Fischer T, Adams R. Paints, varnishes, and lacquers. In: Adams R, ed. *Occupational Skin Disease*. 2nd ed. Philadelphia, PA: W. B. Saunders Co; 1990:426–438.
38. Sasseville D. Acrylates in contact dermatitis. *Dermatitis* 2012;23(1):6–16.
39. Emmett EA. Contact dermatitis from polyfunctional acrylic monomers. *Contact Dermatitis* 1977;3(5):245–248.
40. Goossens A, Coninx D, Rommens K, et al. Occupational dermatitis in a silk-screen maker. *Contact Dermatitis* 1998;39(1):40–41.