

ORIGINAL ARTICLE

Occupational allergic contact dermatitis caused by colophonium

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Background: Colophonium is a common contact allergen that is present not only in household products but also in occupational settings.

Objectives: To describe the sources of occupational exposure to colophonium and the occupations at risk of colophonium allergy.

Methods: We reviewed patch test files from the years 2002 to 2017 at the Finnish Institute of Occupational Health for patients with allergic reactions to colophonium and abietic acid. We analysed the patch test, occupation and exposure data of 39 patients diagnosed with occupational allergic contact dermatitis (OACD) caused by colophonium.

Results: Of the patients examined for suspected occupational dermatitis, 4.6% ($n = 118$) reacted positively to colophonium. The majority of the OACD patients worked in the wood industry, as machinists, or were involved in soldering or agriculture. The most common occupational sources of exposure were coniferous wood and wood-derived materials, followed by glues, metalworking fluids, and soldering materials. Colophonium is not always mentioned in safety data sheets (SDSs), and the sources of colophonium exposure are often materials for which there are no SDSs.

Conclusion: OACD caused by colophonium is quite common and occurs in a variety of occupations. SDSs provide poor information for exposure assessment. Patch testing with the patient's own materials was often useful in establishing the diagnosis.

KEYWORDS

abietic acid, adhesives, chemical analysis, coniferous trees, occupational skin disease, rosin, soldering, wood

1 | INTRODUCTION

Colophonium (syn. colophony or rosin, CAS no. 8050-09-7) is a solid resin obtained from coniferous trees, mostly pines. Major industrial applications of colophonium in unmodified and modified form include the manufacture of printing ink and adhesives, and paper sizing.¹ Colophonium is common in our surroundings, as it is used in various products and applications such as: the adhesives of tapes, plasters, and dressings; polishes; tall oil soap; and some cosmetic products. It may also be present in materials derived from coniferous trees, including timber, sawdust, and paper.¹⁻³ Therefore, exposure to colophonium is likely to be common in both domestic and occupational settings.² The main component of colophonium is abietic acid, the oxidation products of which are considered to be the main contact allergens of colophonium. Colophonium is a common contact allergen, with reported frequencies of patch test positivity of 1.4% to 4.2%⁴⁻⁷

in consecutively patch tested European patients. Trades and occupations in which occupational allergic contact dermatitis (OACD) caused by colophonium has been reported include the wood, paper, electronic and metalworking industries and agriculture, but also beauticians, string musicians, and dental personnel.^{1,3} We wanted to characterize patients diagnosed with OACD caused by colophonium, the occupations and work tasks with a risk of colophonium allergy, and the sources of occupational exposure to colophonium.

2 | MATERIALS AND METHODS

2.1 | Patients and patch testing

For the purposes of the present study, we searched the patch test files of the Finnish Institute of Occupational Health (FIOH) from 2002

TABLE 1 Workers in the wood processing industry with occupational allergic contact dermatitis caused by colophonium (n = 8)

Patient number Year of examination Sex	Occupation /work task	Sources of exposure to colophonium at work	Patch tests with products and materials from worksite ^a	Analysis results	Information from manufacturer
1 2002 F	Cleaner at paper mill	Chip and dust from coniferous wood	NT	-	-
2 2002 F	Manufacture of furniture and packaging boxes	Pine wood dust Rosin on fresh timber Plywood dust	NT NT "as is" –	- - -	- - -
3 2003 M	Worker at paper mill	Dust from carboard 1 Dust from carboard 2 Paper dust Dust from coniferous wood	"as is" ?+, UE + "as is" ?+, UE + "as is" –, UE – NT	Abietic acid 0.09%, dehydroabietic acid 0.23% Abietic acid 0.02%, dehydroabietic acid 0.11% No measurable amount of resin acids -	- - - -
4 2005 F	Manufacture of door frames	Pine wood Chips and sawdust	NT	-	-
5 2007 M	Worker at sawmill	Chips and sawdust from pine timber Chips and sawdust from spruce timber	"as is" + "as is" +	- -	- -
6 2010 F	Manufacture of door and window frames	Pine wood sawdust	"as is" –, UE +	Resin acids total 0.7%	-
7 ^b 2012 M	Chipboard processing in manufacture of furniture	Chipboard dust, sample 1 Chipboard dust, sample 2 Chipboard dust, sample 3	"as is" ++, UE +++ "as is" ?+, UE ++ "as is" –, UE ++	- - -	Chipboards contain 25%-90% coniferous wood
8 2016 M	Manufacture of doors	Chipboard dust, sample 1 Chipboard dust, sample 2 Chipboard dust, sample 3 Dust from MDF board	"as is" ?+, UE ?+ "as is" ?+, UE + "as is" + "as is" ?+, UE ?+	- - - –	Chipboards contain fibres from coniferous trees MDF board contains fibres from coniferous trees

Abbreviations: –, negative; F, female; M, male; MDF, medium-density fibreboard; NT, not tested; UE, ultrasonic extract.

^a Only products and materials with possible relevance regarding colophonium allergy are included.

^b In patient 7, patch test reactions to chipboards were partially caused by his contact allergy to phenol formaldehyde resin.

to 2017 for patients with allergic reactions to colophonium and abietic acid, and the patient files to identify patients diagnosed with OACD caused by colophonium. We analysed data on patch test reactions, occupations, and sources of exposure to colophonium. All of the patients at the FIOH clinic of occupational dermatology are examined for suspected occupational skin disease, and they come from all parts of Finland. Patch testing is performed with Finn Chambers (SmartPractice, Phoenix, Arizona) in accordance with ESCD guidelines.⁸ The tests are read 2 or 3 times (on day [D] 2, D3, and D4; on D2, D3, and D6; or on D2 and D5), depending on the day of the week on which the patch tests were applied. We ask the patients to contact our clinic if they notice new reactions after the final reading.

After patch testing, occupational and non-occupational (domestic) exposure to positive allergens is examined in detail, on the basis

of product information such as safety data sheets (SDSs) and labeling, and, when necessary, by making inquiries to the manufacturers of the products. In selected cases, chemical analyses are conducted on products and materials to exclude or prove the presence of a given allergen in them. During the study period, the patients were tested with colophonium 20% pet. (Trolab/Almirall Hermal, Reinbek, Germany until December 2015, and then Chemotechnique Diagnostics, Vellinge, Sweden), which is included in the baseline series. Some patients were tested with abietic acid 10% pet. (Trolab/Almirall Hermal until May 2015, and then Chemotechnique Diagnostics), which is included in our plastics and oil series. In addition, almost all patients were patch tested with their own products and materials from their workplaces. Ultrasonic extracts were prepared from some solid materials such as wood dusts and paper, with the method described previously.⁹

TABLE 2 Workers in the metalworking industry with occupational allergic contact dermatitis caused by colophonium (n = 6)

Patient number Year of examination Sex	Occupation/ work task	Sources of exposure to colophonium at work	Patch tests with products and materials from workplace ^a	Information on presence of colophonium or related substances in SDS	Analysis results	Information from manufacturer
1 2002 M	Machinist	Metalworking fluid 1	6% aq. ?+	Tall oil fatty acids, esterified	-	-
		Metalworking fluid 2	NT	Tall oil fatty acids, compounds with 2-amino-2-methyl- 1-propanol	-	-
2 2003 M	Machinist	Metalworking fluid 1	10%, 3.2% and 1% pet. -	Not mentioned	Abietic acid 1.61%, resin acids total 5.16%	Contains tall oil fatty acids
		Metalworking fluid 2	10%, 3.2% and 1% pet. -	Not mentioned	Abietic acid 0.02%, resin acids total 0.03%	Does not contain colophonium
3 2003 M	Machinist	Metalworking fluid	10% pet. ++, 3.2% pet. ++, 1% pet. +	Not mentioned	Abietic acid 0.56%, dehydroabietic acid 0.56%, resin acids total 2.25%	-
4 2008 F	Machinist	Metalworking fluid	32% aq. ++, 10% aq. ++	Not mentioned	-	Contains tall oil fatty acids
5 2013 M	Technician; maintenance and repair of metalworking machines	Metalworking fluid	NT	Not mentioned	-	Contains tall oil fatty acids
6 2018 M	Machinist	Lubricant	10% pet. -	Pine oil <2%	-	-

Abbreviations: -, negative; F, female; M, male; NT, not tested; SDS, safety data sheet.

^a Only products and materials with possible relevance regarding colophonium allergy are included.

2.2 | Chemical analysis

In some cases, the patients' own materials were analysed for colophonium. The suspected material was accurately weighed, and extracted with an ethanol-methanol mixture or a tert-butylether-methanol mixture, after which the resin acids were analysed as their methyl ester derivatives with gas chromatography and mass spectrometry (MS). The identification was made by use of the Wiley and National Institute of Standards and Technology MS library, or, in some cases, pure reference compounds.

Abietic acid was patch tested in a total of 1628 patients during the study period. Only 1 patient who reacted positively to abietic acid (+ reaction) had no reaction to colophonium. As colophonium allergy was not confirmed, we excluded this case from further analyses. Abietic acid was patch tested in 69 of the 118 patients with allergy to colophonium, and gave positive (+, ++, or +++) reactions in 41 (59%) patients. Of the 23 patients with +++ reactions to colophonium, 15 were patch tested with abietic acid and 14 showed positive reactions, whereas the percentages of abietic acid positivity among patients with ++ and + reactions to colophonium were 81% and 43%, respectively.

3 | RESULTS

3.1 | Patients and patch test results

During the study period, a total of 2571 patients were patch tested with colophonium 20% pet. Of these, 118 (4.6%) reacted positively to colophonium; 23 (19%) with +++ reactions, 55 (47%) with ++ reactions, and 40 (34%) with + reactions. Of the 118 patients with allergy to colophonium, 90 (76%) were female. OACD caused by colophonium was diagnosed in 39 patients. Among these, 9 showed extreme positive (++++) reactions to colophonium, 21 showed strong positive (++) reactions, and 9 showed weak (+) reactions. The age range of the patients with OACD caused by colophonium was 22 to 60 years, and 24 (62%) of them were female.

3.2 | Occupations and sources of exposure to colophonium

In patients with OACD, the largest occupational group (8 patients) consisted of workers in the wood industry, who were involved in wood processing and the manufacture of wooden products, and, in 1 case, in paper manufacture (Table 1). There were also machinists (6 patients; Table 2), workers involved in soldering (5 patients; Table 3), and farmers (5 patients; Table 4). Construction was represented by 3 patients (Table 5), upholstery by 2, and a variety of occupations by single patients (Table 6).

Among our patients with OACD, the most common sources of occupational sensitization to colophonium were wood and wood-derived materials such as sawdust, coniferous timber (pine and spruce), plywood, chipboard, and wood shavings used as animal

TABLE 3 Workers with occupational allergic contact dermatitis caused by colophonium in soldering materials (n = 5)

Patient number Year of examination Sex	Occupation/ work task	Sources of exposure to colophonium at work	Patch tests with products and materials from worksite ^a	Information on presence of colophonium or related substances in SDS	Analysis results
1 2005 F	Manufacture of light bulbs (soldering and application of lamp capping cement)	Lamp capping cement	20% pet. –	Colophonium	Resin acids 1.2%
		Solder wire	NT	Colophonium 1%-5%	-
2 2006 F	Electronics installer	Solder paste 1	NT	Resin 9%-13%	-
		Solder paste 2	NT	Resin 9%-13%	-
		Solder wire	NT	Modified colophonium <3.4%	-
3 2011 F	Electronics installer	Solder wire 1	NT	Modified colophonium <3.4%	-
		Solder wire 2	NT	Hydrogenated rosin; contains modified colophonium	-
		Solder wire 3	NT	Colophonium 1%-5%	-
		Desoldering braid 1	"as is" (in acetone) +	Colophonium 2%-10%	-
		Desoldering braid 2	NT	Colophonium 2%-8%	-
		Solder paste	NT	Rosin 1%-10%	-
4 2012 F	Electronics installer	Solder wire 1	NT	Colophonium 3%-6%, modified colophonium <3.5%	-
		Solder wire 2	NT	Colophonium 3%-7%	-
		Solder paste	NT	Rosin derivative I (CAS no. 144413-22-9) 1%-5%	-
				Rosin derivative II (CAS no. 64365-17-9) 1%-5%	-
5 2016 M	Maintenance and repair work of hospital devices	Solder flux	NT	Colophonium 50%	-
		Solder wire	NT	Colophonium 3.5%	-

Abbreviations: –, negative; F, female; M, male; NT, not tested; SDS, safety data sheet.

^a Only products and materials with possible relevance regarding colophonium allergy are included.**TABLE 4** Workers in agriculture and animal care with occupational allergic contact dermatitis caused by colophonium (n = 5)

Patient number Year of examination Sex	Occupation/ work task	Sources of exposure to colophonium at work	Patch tests with products and materials from worksite ^a	Information on presence of colophonium or related substances in SDS	Analysis results
1 2002 F	Veterinarian	Tall oil soap	NT	SDS not available. Tall oil soap is known to contain colophonium	-
2 2004 M	Agriculture (dairy farm)	Tall oil soap	10% pet. –	SDS not available. Tall oil soap is known to contain colophonium	-
3 2007 F	Farm relief worker (dairy farms)	Tall oil soap	NT	SDS not available. Tall oil soap is known to contain colophonium	-
		Wood flakes from spruce used as animal bedding	NT	-	-
4 2007 F	Fur farming	Coarse sawdust used as animal bedding	"as is" ?+	-	Resin acids total 0.3%
		Fine sawdust used as moisture binder in fur handling	"as is" ?+	-	Resin acids total 1.5%
5 2015 F	Farm relief worker (dairy farms)	Sawdust and wood flakes used as animal bedding	UE +++	-	-

Abbreviations: –, negative; F, female; M, male; NT, not tested; SDS, safety data sheet; UE, ultrasonic extract.

^a Only products and materials with possible relevance regarding colophonium allergy are included.

TABLE 5 Workers in the construction industry with occupational allergic contact dermatitis caused by colophonium ($n = 3$)

Patient number Year of examination Sex	Occupation/ work task	Sources of exposure to colophonium at work	Patch tests with products and materials from worksite ^a	Information on presence of colophonium or related substances in SDS
1 2008 M	Concrete casting	Mould oil	20% pet. +, 6.4% pet. ?+	SDS: tall oil fatty acid esters
2 2012 M	Carpenter	Fresh and unpeeled pine planks, boards of spruce and sawdust from these	NT	-
3 2014 F	Construction work (house building)	Fresh and unpeeled pine planks	NT	-

Abbreviations: –, negative; F, female; M, male; NT, not tested; SDS, safety data sheet.

^a Only products and materials with possible relevance regarding colophonium allergy are included.

bedding in barns and fur farms (14 cases; Tables 1, 4, and 5). Glues and adhesives were the sources of exposure in 6 cases (Table 6), metalworking fluids in 5 cases (Table 2), solder fluxes and wires in 5 cases (Table 3), and detergent made of tall oil in 4 cases (Tables 4 and 6).

SDSs of 34 colophonium-containing products from the worksites of patients with occupational contact allergy to colophonium were available. Of these, 24 (71%) mentioned the presence of colophonium or some related substance (Tables 2–6). Information on colophonium content was most frequently missing for metalworking fluids (5 of 7 SDSs) and glues (3 of 4 SDSs), whereas the presence of colophonium was indicated in all of the examined SDSs of soldering materials (Tables 2–3, and 6). In 8 OACD patients, chemical analysis of their own workplace substances and materials confirmed occupational exposure to colophonium (Tables 1–3, 5, and 6). These materials were also patch tested “as is”, as ultrasonic extracts, or as both.

Only 3 of the 6 OACD patients in whom glues or adhesives were identified as sources of exposure to colophonium had used liquid glue products. Three patients, among them 1 who also handled glue that contained colophonium in shoe manufacturing, had used colophonium-containing adhesive plasters on their fingers to protect the skin from mechanical strain at work (Table 6). A bank clerk handled envelopes and stickers, the adhesive of which contained resin acids, and papers, which contained up to 0.09% resin acids (Table 6).

Of our patients with non-occupational contact allergy to colophonium, 21 of 79 (27%) reported having had dermatitis caused by an adhesive plaster. Eight (10%) of the non-occupational patients reported dermatitis caused by a skin cream (resin salve) that contained colophonium (wood rosin). This is a popular product marketed for the treatment of scratches, abrasions, small burns and wounds at home, and for the treatment of pressure sores, diabetic wounds, leg ulcers, complicated surgical wound, and burn wounds.

4 | DISCUSSION

We report the experience of examining patients with OACD caused by colophonium at a clinic of occupational dermatology over a period of 16 years. To the best of our knowledge, this is the first report on a large series of patients with OACD caused by colophonium that includes exposure data. In our selected patient population, which consisted of cases of suspected occupational dermatitis, the frequency of

patch test positivity to colophonium was 4.6%. This is slightly higher than the previously reported frequencies of colophonium allergy among patients from occupational settings or with occupational contact dermatitis.^{6,7,10,11}

Colophonium is used and is present in many kinds of applications and materials, and exposure to colophonium is considered to be very common.² Accordingly, our OACD patients represented a wide variety of occupational fields. Occupations in which allergic contact dermatitis caused by colophonium has previously been reported include agriculture workers, horticulturists, wood processing workers, paper and cardboard industry workers, metalworkers, workers involved in soldering, beauticians, string musicians, and dental care professionals.^{1,3,12} Previously reported occupational sources of colophonium exposure include wood dust from coniferous trees,^{13–17} metalworking fluids,^{18,19} soldering flux,^{20,21} paper,^{22,23} cardboard dust,²⁴ fluoride varnish²⁵ and impression material²⁶ in dental care, bow resin in string instruments,^{27,28} ballet dancers' rosin,²⁹ horticulture,³⁰ and industrial extraction of colophonium.³¹ Among our OACD patients, the most frequent occupational field was wood processing, but several patients had handled wood-derived materials in other contexts such as animal bedding.

In accordance with previous literature,^{2,3} glues and metalworking fluids were common sources of exposure to colophonium among our patients. We found that the SDSs of these products often failed to indicate the presence of colophonium, which is a concern. Colophonium has an EU harmonized classification as skin sensitizer 1, and should therefore be indicated by the hazard statement H317 (previously R43) “May cause an allergic skin reaction” in the SDS if the product contains at least 1% colophonium (Regulation [EC] No. 1272/2008). Of the 3 metalworking fluids that were chemically analysed, 2 contained >1% resin acids. Our study shows that patch testing with workplace substances is useful in diagnosing OACD caused by colophonium. For solid materials, the preparation of ultrasonic extracts for patch testing may be helpful. In some cases, it was necessary to analyse the resin acids from workplace materials to confirm occupational exposure to colophonium.

Adhesive tapes, plasters and dressings are common sources of colophonium-allergic contact dermatitis.^{32,33} As our patient population shows, colophonium-allergic contact dermatitis caused by these products is usually non-occupational, but occupational cases do

TABLE 6 Workers in other trades with occupational allergic contact dermatitis caused by colophonium (n = 12)

Patient number Year of examination Sex	Occupation/ work task	Sources of exposure to colophonium at work	Patch tests with products and materials from worksite ^a	Information on presence of colophonium or related substances in SDS and/or product labelling	Analysis results	Information from manufacturer
1 2002 F	Office clerk	Envelope, adhesive surface White paper Sticker sheet, adhesive surface Magazine cover	"as is" +, UE +++ "as is" -, UE +++ "as is" ?+, UE - "as is" -, UE ?+	- - - -	Resin acids 2.7% Resin acids 0.05% Resin acids 4.4% Resin acids 0.09%	- - - -
2 2002 F	Cleaner	Floor cleanser Detergent made of tall oil	5% pet. + NT	Not mentioned in SDS Not mentioned in SDS	- -	Contains colophonium -
3 2003 F	Manufacture of shoes	Glue Adhesive plasters (used on fingers at work)	10% pet. - NT	Not mentioned in SDS -	- -	Colophonium 0.7% -
4 2004 F	Physiotherapist	Adhesive bandage I Adhesive bandage II Adhesive plasters (used on fingers at work)	"as is" - "as is" - NT	- - -	- - -	Contains colophonium Contains colophonium -
5 2006 F	Laboratory technician Analyses for paper and cellulose industry	Sulfate soap (resinous side product of cellulose manufacture) Tall oil soap (prepared in laboratory)	5% pet. ++, 1.7% pet. ++ NT	SDS: rosin acids 18%-50%; abietic acid 25%-60%, dehydroabietic acid 15%-35% -	- -	- -
6 2006 F	Manufacture of car tyres	Tackifying resin in tyre manufacturing (solid)	"as is" ++, UE -	SDS: colophonium 37%	-	-
7 2008 M	Gardener	Rosin from fresh coniferous trees Adhesive plasters (used on fingers at work)	NT NT	- -	- -	- -
8 2012 F	Violinist	Bow rosin I Bow rosin II Bow rosin III Bow rosin IV (synthetic) Glue	"as is" ?+ "as is" ?+ NT NT 5.0% pet. -	- - Labelling: "Hypoallergenic" - SDS: colophonium <0.5%	Abietic acid 10%, dehydroabietic acid 14%, other resin acids 8.6% Abietic acid 17%, dehydroabietic acid 9.3%, other resin acids 25% Abietic acid 27%, dehydroabietic acid 8.5%, other resin acids 31% Resin acids <0.05%	- - - - -
9 2012 F	Boat upholstery	Glue	5.0% pet. -	SDS: colophonium <0.5%	-	-
10 2012 M	Upholsterer	Glue I Glue II	NT NT	Not mentioned in SDS Not mentioned in SDS	- -	Colophonium 0.1%-1% Colophonium 3%

TABLE 6 (Continued)

Patient number Year of examination Sex	Occupation/ work task	Sources of exposure to colophonium at work	Patch tests with products and materials from worksite ^a	Information on presence of colophonium or related substances in SDS and/or product labelling	Analysis results	Information from manufacturer
11 2013 F	Dental therapist	Fluoride lacquer/varnish	NT	SDS: colophonium 30%-60%	-	-
12 2016 F	Beautician	Epilatory cream Skin cream Skin lotion Skin cleanser Foot bath	NT NT NT NT NT	INCI: glyceryl rosinat INCI: <i>Cyperus sempervirens</i> extract INCI: <i>Cyperus sempervirens</i> extract INCI: <i>Cyperus sempervirens</i> extract INCI: juniper berry extract	- - - - -	- - - - -

-: negative; F, female; INCI, International Nomenclature of Cosmetic Ingredients; M, male; NT, not tested; SDS, safety data sheet; UE, ultrasonic extract.
^a Only products and materials with possible relevance regarding colophonium allergy are included.

sometimes occur. Adhesives for shoe linings have been reported as causes of allergic contact dermatitis in patients who are allergic to colophonium.³⁴ Among our patients with OACD caused by colophonium, only a few cases were associated with the use of colophonium-containing glues or sealants. In the case of one of our patients, the identified source of colophonium was the adhesive in the envelopes and stickers that she handled at work. This patient had an extreme positive test reaction (+++) to colophonium, and she also reacted to an ultrasonic extract prepared from a sheet of paper from her workplace. Cases of allergic contact dermatitis caused by paper have been described previously.^{22,35-37} As the colophonium content of paper materials is expected to be very low, patch testing with ultrasonic extracts might be useful if contact dermatitis caused by paper materials is suspected.

Cosmetics that contain colophonium, such as epilating products and mascaras, have caused allergic contact dermatitis among consumers and professionals.³⁸⁻⁴¹ One of our patients with OACD caused by colophonium was a beautician. In her work, she handled cosmetic products that contained natural resins, balsams or extracts of resinous plants, such as glyceryl rosinat and *Cyperus sempervirens* extract, and resin extracts from the non-coniferous trees *Boswellia serrata* and *Styrax benzoin*, which have been described as contact allergens in patients who are also allergic to colophonium.⁴²⁻⁴⁴ According to the literature, concomitant patch test reactions to colophonium, fragrance allergens and Compositae allergens are frequent.⁴⁵ Our patient had concomitant test reactions to, for example, fragrance mix, Compositae mix, *Myroxylon pereirae* (balsam of Peru), *Evernia furfuracea*, cedarwood oil, and peppermint oil.

OACD caused by colophonium in bow rosin is well described among string musicians.^{28,46-48} Our patient series included a violinist, for whom we analysed the resin acids in 4 bow rosins. As expected, 3 of the bow rosins contained substantial amounts of resin acids. The rosin with the highest content of abietic acid was labelled "hypoallergenic". The fourth bow rosin was a so-called synthetic rosin with a low content of resin acids. However, our patient found the technical properties of the synthetic rosin unsatisfactory and felt unable to switch to it.

As colophonium is a natural substance, its composition is variable and complex.¹ It mainly consists of resin acids, the most abundant of which are abietic acid isomers. Although the oxidation products of abietic and dehydroabietic acids are considered to be the main allergens of unmodified colophonium,^{32,49} the neutral components of colophonium may also be oxidized to allergenic compounds.⁵⁰ Our finding that patch testing with abietic acid gave positive reactions in only 59% of the patients with contact allergy to colophonium might imply that their actual allergen was some other component of colophonium. Alternatively, the test substance for abietic acid possibly had a lower content of oxidation products than the test substance for colophonium.

For various industrial purposes, colophonium is often chemically modified to improve its technical properties. New allergens are formed through chemical modification of abietic acid and its isomers, and the final product may contain allergens from unmodified colophonium and new ones formed by modification,¹ such as maleopimaric acid, which is a strong sensitizer with no cross-reactivity to the

allergens of unmodified colophonium.^{51,52} One limitation of our study was that we did not screen our patients with allergens of modified colophonium.⁵³ Therefore, we might have missed patients with contact allergy to modified colophonium.⁴²

In conclusion, the occupations predominantly at risk of OACD from colophonium include workers in the wood industry, machinists, and workers involved in soldering and agriculture. The most common sources of occupational exposure to colophonium are wood and wood-derived materials, glues, metalworking fluids, and soldering materials. Patch testing with workplace substances may be necessary to detect occupational exposure to colophonium.

Conflict of interest

M.P. has received a lecture fee from Leo Pharma and the Finnish Cosmetic, Toiletry and Detergent Association. The other authors declare no potential conflict of interests. There was no external funding.

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