

Asthma due to inhaled chemical agents— fumes from 'Multicore' soldering flux and colophony resin

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Summary

Four patients with occupational asthma associated with exposure to soldering flux or hot-melt glue containing pine resin (colophony) were subjected to occupational type inhalation challenge testing.

All four gave immediate bronchial reactions to inhalation of the fumes, varying from one breath to 3 min of exposure.

The clinical history and provocation test reactions suggest hypersensitivity to colophony fumes.

Introduction

Occupational asthma due to fumes from aluminium soldering flux is well recognized and was shown by Sterling (1967) to be caused by fumes of aminoethyl-ethanolamine from the flux. Three similar cases were studied in more detail by Pepys & Pickering (1972) using simulated occupational exposure.

Using similar test procedures we have studied three patients with asthma induced by soldering fumes from a pine resin based flux incorporated in 'Multicore' tin-lead solder used for soldering steel wires and a fourth subject who developed asthma after exposure to the pine resin used as a constituent of a hot-melt glue.

Materials and methods

'Multicore' solder is a tin-lead alloy produced as a strip containing multiple cores of wood resin flux. The flux is based on colophony, the resin obtained from pine trees (Hillis, 1962). It consists of about 90% resin acid, the principal of which is abietic acid, with 10% neutral material such as stilbene derivatives and various hydrocarbons. The flux also contains an organic amine hydrochloride activator which helps to clean the joint being soldered by releasing hydrochloric acid when heated.

The tests were made in a cubicle $2.65 \times 1.65 \times 1.45$ m (approximately 6 m^3). The occupational type exposures consisted of applying the heated soldering iron to 'Multicore' solder or to 1 g of the pine resin (colophony) in a stainless steel pot.

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Soldering temperatures (approximately 400°C) cause visible fumes to be produced from the flux. Vapour produced by heating carbol-saline in a steel pot with a soldering iron was used as control in the first two subjects. The other two were observed during a hospital day as a control day. The fourth subject was also exposed to the fumes of hot-melt glue obtained by brushing the heated liquid glue (60°C) onto a wooden board.

Minimal exposures were used, starting with one natural breath of the fumes in the most sensitive subjects. Only one test was made on one day, and if no reaction was obtained the exposure was increased on successive days.

Respiratory function tests were performed before the exposure, at 10 min intervals for 1 hr afterwards, and then hourly for at least 8 hr. A dry wedge spirometer (Vitalograph) was used to record forced expiratory volume in 1 sec (FEV₁) and forced vital capacity (FVC).

Case histories

(1) *Patient G.P.* was a 27-year-old man who had had perennial asthma from age 6 to 12 years. At the age of 17 he started work in an electronics factory using 'Multicore' solder. After 1 year he began to have asthmatic symptoms which started about 15 min after using the solder and persisted for up to 1 hr. He only had attacks of asthma during the working week and was well at weekends. Because of this, he changed to clerical work with considerable improvement. The use of 'Multicore' solder at home in his hobby of making radio sets, provoked further attacks of asthma. At the time of investigation he had not been exposed to soldering flux for several months.

Physical examination and chest X-ray were normal. Investigations: haemoglobin, white cell count and absolute eosinophil count were within normal limits. Routine prick tests with twenty-three common allergens gave positive reactions to grass pollen and to *D. pteronyssinus*.

Pulmonary function tests

	Result	% predicted	After inhalation of Salbutamol
FEV ₁ ml	3400	77.8	3800
FVC ml	4960	94.4	5350
FEV ₁ /FVC	65%	—	71%
VC ml	5450	110	5550
TLC ml	7430	109	
FRC ml	4730	126	
RV/TLC	34.7%		
DLCO	32.3	144	
(Single breath method)			

(2) *Patient J.W.* was a 42-year-old woman who developed asthmatic symptoms at the age of 39 years. Three years previously she had started work in an electronics factory, soldering printed circuits for radios, in a large workroom with approximately 200 others doing similar work. She developed a dry cough and wheeze after about 5 hr on the shift and the wheezing persisted into the evening. These symptoms recurred on each day of the working week, but were absent at weekends and during holidays.

One year before investigation she was transferred to a clean air zone to work on

miniature electrical circuits but there were still visible fumes in the room. She continued to have asthma, which became more severe. Treatment with bronchodilators and inhaled corticosteroids failed to control her symptoms.

There was no personal or family history of allergic disorders.

Physical examination was normal apart from moderate expiratory wheeze. Chest X-ray was normal. Investigations: haemoglobin, white cell count and absolute eosinophil counts were in the normal range. Prick tests with twenty-three common allergens were negative.

Pulmonary function tests

	Result	% predicted	After inhalation of Salbutamol
FEV ₁ ml	2420	84	2800
FVC ml	4000	114	4000
FEV ₁ /FVC	60.5%	—	70%
VC ml	4075	116	
TLC ml	5830	113	
FRC ml	3380	116	
RV/TLC	30.1%	—	
DLCO	22.8	100	
(Single breath method)			

(3) *Patient V.G.* was a 46-year-old woman who had worked for 4 years in an electronics factory soldering printed circuits using 'Multicore' solder. She had suffered from infantile eczema as well as rhinitis and asthma during childhood. These complaints improved during her twenties, and she had only occasional wheezing, usually in association with respiratory tract infections. However, after 3 years' employment in the electronics factory, the asthma became worse and she developed symptoms of chest tightness and breathlessness 2–3 hr after starting work, and persisting into the evening. There were no symptoms during weekends, and during a month away from work when she was completely free of symptoms. Within 3 hr of returning to work, the symptoms recurred.

Physical examination and chest X-ray were normal. Investigations: haemoglobin, white cell count and absolute eosinophil count were in the normal range. Prick tests with twenty-three common allergens gave positive reactions to house dust extract.

Pulmonary function tests

	Result	% predicted	After inhalation of Salbutamol
FEV ₁ ml	1350	56	1450
FVC ml	2050	67	2200
FEV ₁ /FVC	66%		66%
Raw (at FRC)	5.49		1.76
TLC ml	4560	99	4240
FRC ml	3310	124	2840
RV/TLC%	55		48.1

Her respiratory function was too poor at the beginning of the investigation for inhalation tests. She was therefore put onto 4 hourly inhalations of Salbutamol 200 µg. Her pulmonary function tests improved sufficiently for inhalation tests to be made (see control day of diagram).

(4) *Patient G.S.* was a 49-year-old man who worked as a supervisor in a pet food company. He had no history of eczema, hay fever or asthma during childhood. At the age of 43 he noticed that exposure to a hot-melt glue which was used for labelling the cans, provoked sneezing and rhinorrhoea, followed after 3-4 hr by wheezing. His symptoms improved at weekends and during a 1-year period when he was transferred to an outside job. He was then promoted to a supervisory job inside the factory and his symptoms returned immediately.

Physical examination and chest X-ray were normal. Investigations: his blood count was normal with no eosinophilia and prick tests to twenty-three common allergens were negative. He had a sputum eosinophilia of over 70%.

Pulmonary function tests

	Result	% predicted	After inhalation of Salbutamol
FEV ₁ ml	3800	111	4000
FVC ml	4950	106	4900
FEV ₁ /FVC%	76.7		81.6
VC	4500	96	
TLC	6560	104	
FRC	4130	94	
RV/TLC	31.4	95	
DLCO	36.8	126	
(Single breath method)			

Constituents of hot-melt glue

Analysis of the hot-melt glue provided by the manufacturers showed that it contained pine tree resin (colophony), a major constituent of which is abietic acid. It also contained paraffin wax and an ethylene vinyl acetate copolymer.

Inhalation tests and results

(1) Patient G.P.

The following tests were made:

- (1) Carbol-saline vapour, three breaths, control day.
- (2) 'Multicore' solder fumes, three breaths.
- (3) Inhalation of 20 mg sodium cromoglycate 15 min before three breaths of 'Multicore' solder fumes.
- (4) Inhalation of 20 mg lactose placebo 15 min before three breaths of 'Multicore' solder fumes.

Result (Fig. 1). There was no reaction to the control test. Three breaths of fume from 'Multicore' solder (Tests 2 and 4) elicited immediate asthmatic reactions lasting for about 30 min with maximum falls in FEV₁ to 62% and 48% of the pre-exposure values respectively. Prior inhalation of sodium cromoglycate (Test 3) blocked this reaction, whereas the lactose placebo (Test 4) did not.

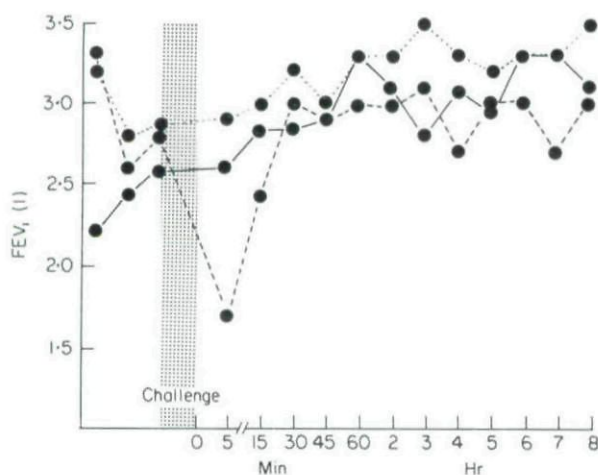


Fig. 1. Patient G.P. Immediate asthmatic reaction to fumes of 'Multicore' solder and inhibition by sodium cromoglycate. —, Control day; ---, 'Multicore' solder, 3 inhalations; ···, 'Multicore' solder, 3 inhalations, Intal pretreatment.

(2) Patient J.W.

The following tests were made:

- (1) Carbol-saline vapour, ten breaths, control day.
- (2) Fumes from soldering of steel wire using 'Multicore' solder and liquid resin flux for 10 min.
- (3) 'Multicore' solder fumes, 3 min exposure.
- (4) Inhalation of 20 mg sodium cromoglycate before 3 min exposure to fumes of 'Multicore' solder.
- (5) Colophony resin fumes, three breaths.
- (6) Colophony resin fumes, ten breaths.
- (7) Inhalation of 20 mg sodium cromoglycate before ten breaths of colophony resin fume.

Results (Fig. 2a, b, c). Test 1 with carbol saline vapour as control was negative. Test 2: the fumes from the materials used at her work caused an immediate asthmatic reaction with a maximum FEV_1 fall of 64%. She was given intravenous aminophylline with return of the FEV_1 to pre-test values within 2 hr. The asthma recurred later, with a maximum fall of 40% in FEV_1 at 7 hr (Fig. 2a).

Test 3: 3 min exposure to 'Multicore' solder fume caused an immediate asthmatic reaction only, with a maximum FEV_1 fall of 50% at 15 min. Test 4 shows that this reaction was blocked by pre-treatment with sodium cromoglycate (Fig. 2b).

Inhalation tests were then done using fumes from colophony resin alone.

Test 5: three breaths of the fume did not provoke a reaction, whereas in Test 6 with ten breaths, there was an immediate asthmatic reaction with a 40% fall in FEV_1 at 15 min followed by a late reaction with a maximum fall of 56% in FEV_1 at 6 hr, which was reversed by inhalation of 200 μ g of Salbutamol. Pre-treatment with sodium cromoglycate (Test 7) did not inhibit the immediate reaction to the colophony but had an inhibitory effect on the late reaction.

No blood eosinophilia or leucocytosis was recorded during these bronchial reactions.

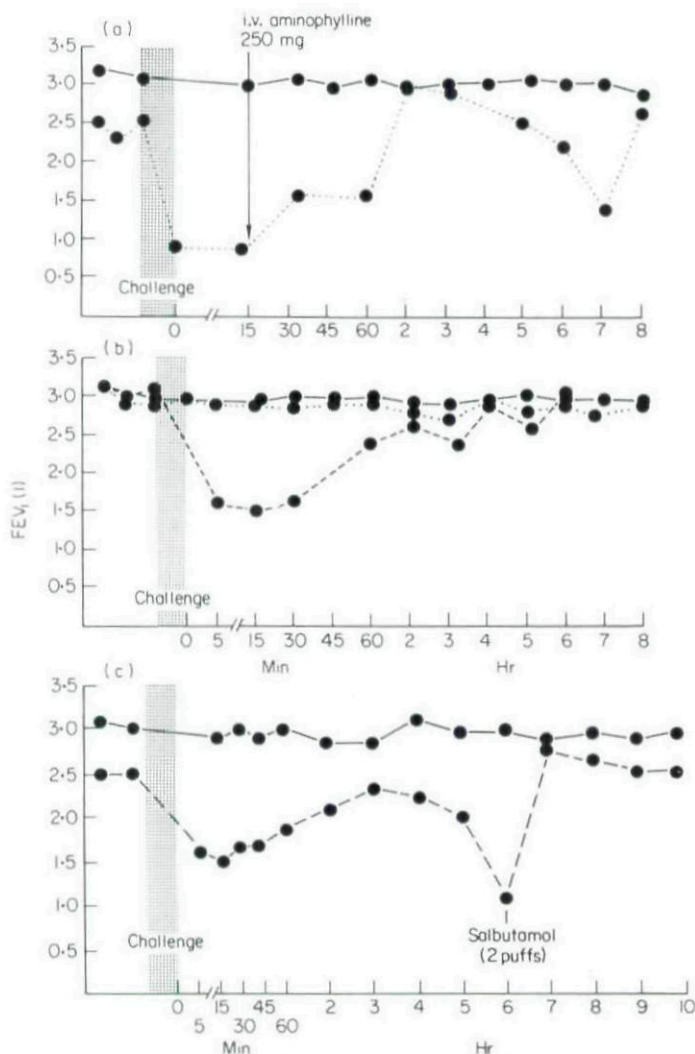


Fig. 2. (a) Patient J.W. Immediate and non-immediate asthmatic reactions to fumes of 'Multicore' solder and flux. —, Control day; ···, soldering wire with 'Multicore' solder and liquid flux for 10 min.

(b) Inhibition of immediate reaction by sodium cromoglycate. —, Control day; ---, 'Multicore' solder, 3 min inhalation; ···, 'Multicore' solder, Intal pretreatment.

(c) Immediate and non-immediate asthmatic reactions to colophony fumes. —, Control day; ---, colophony ten breaths.

(3) Patient V.G.

The following tests were made:

(1) Control day; 4-hourly inhalations of Salbutamol 200 μ g at 06.30, 10.00, 14.30, 18.30 and 22.30 hours to establish a stable ventilatory state.

(2) Four-hourly inhalations of Salbutamol 200 μ g as above. Exposure to fumes from the soldering of plastic coated steel wire with 'Multicore' solder for 20 min.

(3) Four-hourly inhalations of Salbutamol 200 μ g as above. Fumes from the heating of only the plastic coated wire with soldering iron for 30 min.

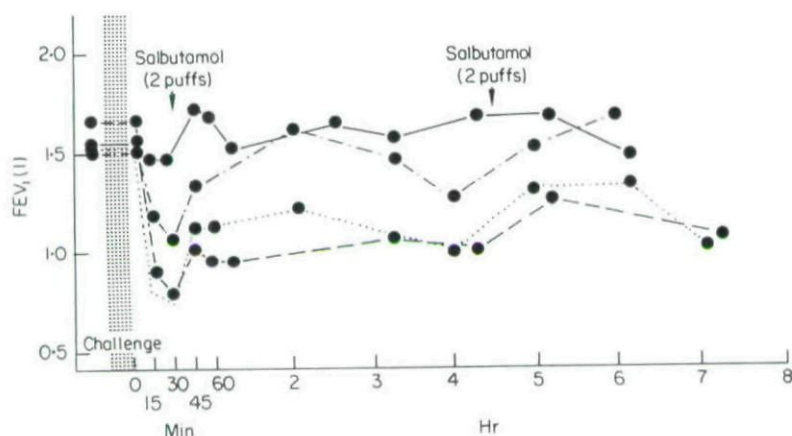


Fig. 3. Patient V.G. Immediate and non-immediate asthmatic reactions to fumes from 'Multicore' solder and colophony. —, Control day; ---, wire/'Multicore' solder 20 min inhalation; ···, 'Multicore' solder 30 min inhalation; - · -, colophony five breaths.

(4) Four-hourly inhalation of Salbutamol 200 μ g as above. Fumes from the heating of only the 'Multicore' solder with soldering iron for 30 min.

(5) Four-hourly inhalations of Salbutamol 200 μ g as above. Fumes from heated colophony resin, five breaths.

Result (Fig. 3). On the control day (Test 1) using regular inhalations of Salbutamol, her FEV₁ showed no significant variation. Test 2: soldering of the plastic coated wire with the 'Multicore' solder provoked an immediate bronchial reaction with a fall in FEV₁ from 1.65 l to 0.8 l, maximal 30 min after exposure and not returning to pre-challenge values until the following morning. Test 4: similar reactions were provoked by exposure to the 'Multicore' solder fumes, and in Test 5 to colophony resin. Test 3:

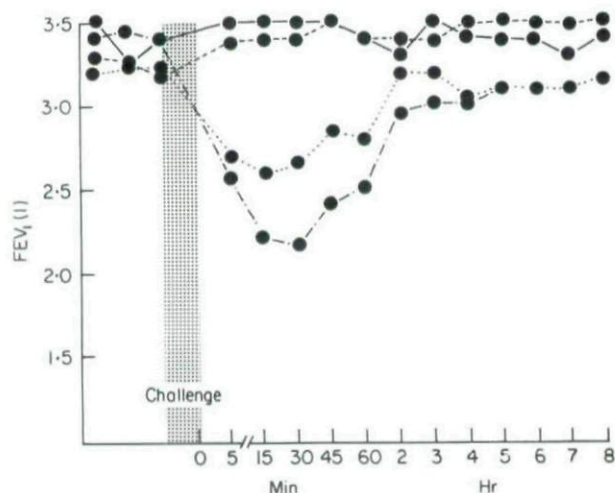


Fig. 4. Patient A.S. Immediate asthmatic reaction to colophony fumes and to hot melt glue. Inhibition of reaction by sodium cromoglycate. —, Control day; ···, colophony, 3 min inhalation; ---, colophony, Intal pretreatment; - · -, painting for 15 min with resin glue.

exposure to the fumes produced by heating the plastic covering on the wire provoked no reaction.

(4) *Patient A.S.*

The following tests were made:

- (1) Control day, no challenge.
- (2) Painting with hot-melt glue for 15 min.
- (3) As in Test 2, but after pretreatment with sodium cromoglycate 20 mg.
- (4) Colophony resin fume, 3 min inhalation.
- (5) Inhalation of sodium cromoglycate 20 mg before colophony resin fumes for 3 min.

Results (Fig. 4). Test 2: painting with hot-melt glue provoked an immediate asthmatic reaction with a maximum fall in FEV_1 of 37% at 30 min. Test 3 shows that this reaction was partially blocked by sodium cromoglycate. Test 4: challenge with colophony fumes elicited an immediate reaction with a maximum FEV_1 fall of 20% at 20 min returning to the pretest value by 90 min. Test 5 shows that this reaction was blocked by sodium cromoglycate (Fig. 4).

Discussion

Colophony is widely used in soldering fluxes as in 'Multicore' and in liquid resin soldering fluxes. When colophony is heated to soldering temperatures of about 400°C, it releases abietic acid as fume and a series of thermal decomposition products which include hydrocarbons and aliphatic aldehydes (Lawrence, 1959; American Conference of Governmental Industrial Hygienists, 1971).

The workers described in the present report all had asthmatic reactions following exposure to very low atmospheric concentration of flux or resin fumes, although different degrees of exposure were required to elicit the reactions. Under their usual occupational conditions, they were exposed to such fumes for much longer periods, and their histories provided evidence of far more severe and prolonged asthmatic attacks.

In each case occupational type inhalation tests were made to try and identify the causal agents. Colophony resin fumes were found in all cases to cause bronchial asthma similar to that experienced at work. The flux activator in 'Multicore' solder was not tested in these patients but is currently under investigation. These tests were made after a period away from work and during this time the ventilatory function of three of the four patients' had returned to within predicted normal limits. In one of the patients, regular inhalation of Salbutamol was required to achieve stable lung function so that tests could be made.

The patients presented with traditional criteria for hypersensitivity. In each factory only a few of the exposed workers were affected and the asthma developed only after repeated exposures. It then recurred regularly on re-exposure at work and in one subject during his hobby activity of making radios. The reactions were blocked by sodium cromoglycate as has been reported, for asthmatic reactions to common allergens where there is supporting evidence for immunological mechanisms, and for asthmatic reactions to a wide variety of chemical agents for which such evidence is lacking (Pepys & Hutchcroft, 1975).

The challenge test thus identified the occupational cause of the asthma in these workers and made it possible to guide them on their future employment.

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