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The effects on asthmatics of exposure to a conventional water-based and a volatile organic compound-free paint

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The effects on asthmatics of exposure to a conventional water-based and a volatile organic compound-free paint. J.R. Beach, J. Raven, C. Ingram, M. Bailey, D. Johns, E.H. Walters, M. Abramson. ©ERS Journals Ltd 1997.

ABSTRACT: The water-based paints now frequently used for house painting still contain small amounts of volatile organic compounds (VOCs), with the potential to exacerbate symptoms of asthma. Because of these potential problems and environmental concerns, some manufacturers have produced paints with no VOC content. We wished to compare the effects on asthmatics of conventional water-based paint and the new VOC-free paint.

Seventeen asthmatics were recruited on the basis of having previously reported exacerbation of symptoms by paint or other odours. Each undertook a standard painting task with identically coloured conventional acrylic and VOC-free paints in a double-blind, crossover study. Respiratory symptoms, lung function, and airway responsiveness were measured at each visit.

A significant increase in reported "wheeze" was detected during use of conventional paint ($p<0.01$), but not with the new paint. There was also a significantly greater increase in reported "breathlessness" whilst using conventional paint than with the new paint ($p<0.05$). In contrast, lung function measurements showed a small but significant increase during the use of both paints ($p<0.05$). There was no significant change in airway responsiveness after use of either paint.

The new paint appears to be less likely to cause a worsening of respiratory symptoms than conventional acrylic paint, although this difference is not reflected in measurements of lung function or airway responsiveness. Although the benefit conferred in the majority of asthmatics is probably modest, there may be some patients with an increased sensitivity to paint odour, who would derive a useful symptomatic benefit from using the VOC-free paint.
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Anecdotally, many people with asthma notice that their symptoms are made worse if they are exposed to the smell of paint from a recently painted surface. Whilst epoxy resin or isocyanate-based paints are well recognized causes of asthma, normal household paints are not generally considered capable of causing asthma. However, there has been relatively little research in this field. In the UK, the Surveillance of Work-related and Occupational Respiratory Disease (SWORD) scheme has reported a number of painters (who were not spray painting) with work-related asthma [1, 2]. Although the exact composition of the paints was not reported, these reports may be related to the paint types already implicated as causes of asthma. Similarly, paints and solvents are implicated as causative agents in a report of claims for occupational asthma submitted to the Ontario Workers Compensation Board, although again it is impossible to separate claims due to paint types known to cause asthma and conventional household paints [3].

In response to this evidence, and increasing environmental concerns about the use of volatile solvents, a number of paint manufacturers have reduced the amount of volatile solvents in paints by switching to water-based paints. However, most still contain a proportion of volatile solvents, and produce a noticeable odour, thus retaining the potential to exacerbate asthma symptoms [4, 5]. One recent study reported a cross-shift decrease in forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) in a group of painters using water soluble paints, and increased airway responsiveness and decreased FEV_1 in a group of painters using water-based paints, compared with a comparison group [6].

Some manufacturers have recently produced paints without any volatile solvents (volatile organic compound (VOC)-free). It may be that these are less likely to cause a worsening of asthma than more traditional paints, but at present there is little or no evidence to support this belief. Consequently, we compared the effects of using a traditional water-based paint and a VOC-free paint on respiratory symptoms, spirometry, and airway responsiveness to methacholine among a group of asthmatic subjects in a double-blind, crossover study.

Materials and methods

Study subjects

Seventeen asthmatic subjects, aged 18–65 yrs, were recruited from a database of volunteers held by the Department of Respiratory Medicine, and from advertising in local newspapers. All reported that exposure to the odour of paint or other strong odours would exacerbate their asthmatic symptoms.

Subjects with an exacerbation of their asthma or change in their medication within the preceding 6 weeks or during the course of the study were excluded, as were subjects with an FEV_1 <60% predicted or 1.5 L (whichever was the greater), or with a serious concurrent disease. Females were excluded if pregnant or lactating, or if not using adequate contraception.

Study design

The study had a double-blind, crossover design. Each subject made three randomized visits to the laboratory at the same time of day (±1 h) with at least one rest day between visits. All visits for each subject were completed within a maximum of 28 days. Short-acting bronchodilators were withheld for 6 h before each visit, whilst inhaled steroids were taken at their usual time. Long-acting bronchodilators were not permitted during the study.

Methods

At the first visit, informed consent was obtained and subjects underwent spirometry and an inhalation methacholine challenge test using a standardized dosimeter method [7]. The two subsequent visits required the subject to paint a 2.7 m^2 board over a period of 60 min, using either a conventional low sheen water-based interior paint or a new VOC-free paint (Breathe Easy™; Dulux, Australia). On all occasions, painting was performed with a paintbrush using identically coloured white paint. Painting was undertaken in a room adjacent to the laboratory with a volume of approximately 32 m^3, supervised by one of the investigators. Respiratory symptoms, mucosal irritation, and discomfort were recorded on 100 mm visual analogue scales (VAS), and spirometry was performed at 15 min intervals throughout the period of painting. Spirometry was performed using a wedge bellows spirometer (Vitalograph, Buckingham, UK) measuring FVC, FEV_1 and forced mid-expiratory flow ($FEF_{25–75}$), with all values being corrected to body temperature, atmospheric pressure and saturation with water vapour (BTPS). At the conclusion of each 60 min painting period, subjects returned to the main pulmonary function laboratory and performed a further set of spirometric measurements (*i.e.* approximately 5–10 min after finishing painting) and underwent a methacholine test. The provocative dose of methacholine causing a 20% fall in FEV_1 (PD_{20}) was estimated by linear interpolation, and dose-response slope (DRS) was also estimated [8].

Analysis

Analyses of spirometric values were initially performed to take account of the measurements made throughout each painting period using analysis of variance (ANOVA), *i.e.* to determine if there was a significant change from time 0. When ANOVA identified a significant change at any time, a Student's t-test was used to identify which of the individual time-points gave rise to this significant change. No statistically significant order effects were identified for any of the parameters measured, and thus the crossover nature of the study was utilized, data from both visits being used to make comparisons between paints. Change in spirometric values for each subject during each painting period were compared using ANOVA, *i.e.* to determine if there was a significant difference between paints in change from time 0. Symptom scores were analysed using equivalent nonparametric techniques (Wilcoxon signed rank sum test and Friedman's test adjusted for ties). Airway responsiveness data were log-transformed and analysed using ANOVA to compare PD_{20} and DRS at each visit. Analyses were performed using Minitab (release 10) statistical software (Minitab Inc, State College, PA, USA).

Approval for the study was given by the Ethics Review Committee of the Alfred Healthcare Group.

Results

Six male and 11 female asthmatic patients with a mean age of 42 (range 19–64) yrs, were recruited. All were taking inhaled bronchodilators, and 14 were using inhaled steroids (median dose 800 µg daily). No subjects were using oral corticosteroids, oral bronchodilators, or theophylline. Baseline lung function results suggested mild airflow limitation and moderate airway responsiveness (table 1). Mean (SD) FEV_1 was 88 (21)% pred at the baseline visit.

All subjects were able to complete a period of 60 min painting with both paints, without undue distress. One subject had a >10% fall in FEV_1 with saline inhalation during the methacholine test after both painting challenges, and so could not complete the methacholine

Table 1. – Lung function and airway responsiveness of study volunteers at baseline visit and following use of each paint

	Baseline visit	Conventional paint	VOC-free paint
FEV_1# L	2.68 (0.75)	2.63 (0.77)	2.64 (0.81)
FEV_1/FVC# %	69 (10)	70 (12)	72 (13)
Mean $FEF_{25–75}$# $L \cdot s^{-1}$	1.95 (1.14)	1.97 (1.17)	1.97 (1.23)
PD_{20}‡ µg	52	67	54
DRS‡ %/µg	0.40	0.33	0.35

#: values are presented as mean, and SD in parenthesis; ‡: geometric mean value. VOC: volatile organic compound; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; $FEF_{25–75}$: forced mid-expiratory flow; PD_{20}: provocative dose of methacholine causing a 20% fall in FEV_1; DRS: dose-response slope.

test. One additional subject did not attain a >20% fall in FEV_1 at the maximum dose of methacholine at one of the painting visits. Thus, symptom scores and spirometry results were available for all subjects at all time points, whereas DRS could only be estimated for 16 subjects and PD_{20} for 15 subjects at all visits.

Median scores for subjective symptoms of "unpleasant taste" (value of Friedman two way ANOVA test statistic (S)=14.6; degree of freedom (df)=4; p<0.01) and "wheeze" (S=13.6; df=4; p<0.01) (fig. 1) increased significantly from 0 to 60 min during exposure to conventional acrylic paint but not during exposure to the VOC-free paint. On the other hand the median "unpleasant smell" score increased significantly during exposure to the VOC-free paint (S=14.7; df=4; p<0.01) but not with exposure to conventional paint. No statistically significant changes were noted in median symptom scores during exposure for any other symptoms, except that the median score for "headache" was significantly worse after 45 min exposure to conventional paint (S=14.8; df=4; p<0.01), but by 60 min this difference was no longer statistically significant.

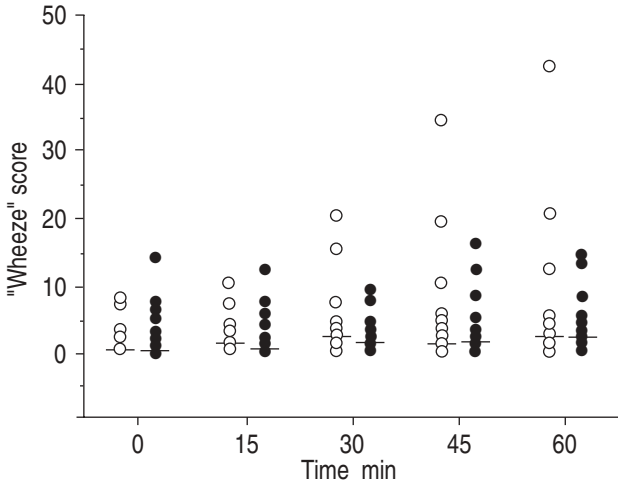

Fig. 1. – "Wheeze" score (out of 100) at each time-point when using each paint. ○ : conventional paint; ● : volatile organic compound-free paint. Horizontal bars represent the median values.

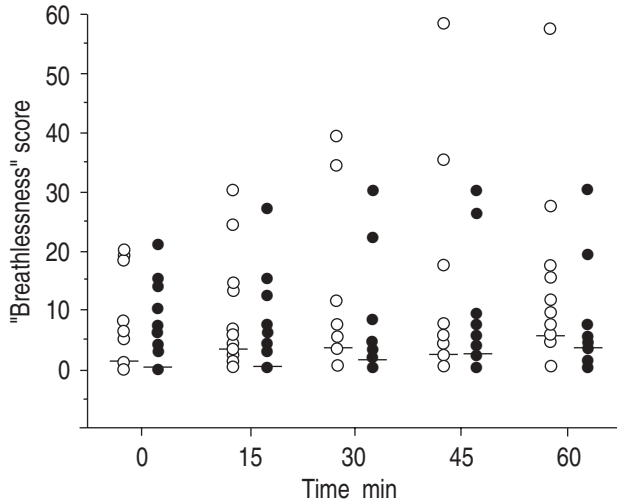

Fig. 2. – "Breathlessness" score (out of 100) at each time-point when using each paint. ○ : conventional paint; ● : volatile organic compound-free paint. Horizontal bars represent the median values.

For almost all symptoms there was a greater increase from 0 to 60 min in median symptom scores with the conventional than with the VOC-free paint, but few of these differences between paints were statistically significant. The change in median symptom scores for "breathlessness" were significantly greater for the conventional than the VOC-free paint (p=0.031), with median score increasing from 1 (range 0–20) to 5 (range 0–57) with conventional paint, and from 0 (range 0–21) to 3 (range 0–30) with VOC-free paint (fig. 2).

Lung function improved during exposure to both paints (table 2). With conventional paint, mean FEV_1 increased by 87 mL between 0 and 60 min ($F_{4,64}$=3.87; p<0.01), and by 81 mL with VOC-free paint, although this did not achieve statistical significance ($F_{4,64}$=2.35; $0.1 > p > 0.05$). With conventional paint mean $FEF_{25–75}$ improved by 195 $mL \cdot s^{-1}$ between 0 and 60 min ($F_{4,64}$= 4.63; p<0.01), and with VOC-free paint by 197 $mL \cdot s^{-1}$ ($F_{4,64}$=2.89; p<0.05). There were no significant differences in the changes in lung function between paints.

There were no statistically significant differences in mean airway responsiveness between any of the visits, whether estimated as PD_{20} or DRS (table 1).

Discussion

These results suggest that for asthmatic individuals there is a difference between conventional acrylic water-based paints and the new VOC-free paint (Breathe Easy™) in terms of the symptoms of wheeze and breathlessness that are produced during exposure to vapour from paint over a period of 1 h (figs. 1 and 2). Although these differences were relatively small, they were nonetheless statistically significant. However, for the majority of subjects, symptom scores recorded were low throughout with both paints, and no subject, at any time, became sufficiently distressed that painting had to be discontinued. However, from a clinical perspective, it

Table 2. – Lung function during exposure to paints

	Time-point min 0	15	30	45	60	p-value
Conventional paint						
FEV_1 L	2.42 (0.70)	2.49 (0.76)	2.53 (0.77)	2.51 (0.73)	2.51 (0.70)	<0.01
$FEF_{25–75}$ $L \cdot s^{-1}$	1.72 (1.01)	1.87 (1.05)	1.95 (1.11)	1.91 (1.12)	1.92 (1.02)	<0.01
VOC-free paint						
FEV_1 L	2.45 (0.74)	2.48 (0.73)	2.49 (0.70)	2.51 (0.72)	2.53 (0.75)	>0.05
$FEF_{25–75}$ $L \cdot s^{-1}$	1.74 (0.99)	1.83 (1.08)	1.86 (1.15)	1.87 (1.05)	1.94 (1.17)	<0.05

Values are presented as mean, and SD in parenthesis. For definitions see legend to table 1.

was apparent from the data that the difference between groups appeared to be largely due to a few individuals who developed relatively high symptom scores during exposure to the conventional paint, but not with the VOC-free paint. It would seem that individual sensitivity, even in this selected group, is an important factor in determining symptoms.

In contrast to the changes in symptoms, there were no differences between paints in mean lung function either during or after exposure, or in airway responsiveness measured immediately after exposure. In fact, lung function showed a small but statistically significant increase during the course of testing with both paints. We were unable to find a convincing explanation for these improvements in lung function. They did not appear to be related to the time of day a subject was tested and, hence, to diurnal variation, but may represent a "training effect". Interestingly, change in symptoms showed little relationship to change in spirometry, and those subjects with the greatest change in symptoms were not those with the greatest change in FEV_1 or FEF_{25-75}. Regardless of the cause of the improvement, it would appear that paint exposure at the levels encountered in this study does not have a detrimental effect on lung function.

It might be postulated that lung function and airway responsiveness were measured before physiological deterioration had time to occur, although we believe this to be unlikely. Classically, late asthmatic reactions to occupational allergens and the associated changes in airway responsiveness occur several hours after exposure. Although this is the case with agents whose effect is mediated through immunological sensitization, we felt it more likely that any effect from the paints used in this study would be due to a direct irritant mechanism, and so most likely to be detected immediately. Also, no subject reported symptoms suggestive of a late asthmatic reaction when they reattended, and so we are reasonably confident that we did not miss clinically relevant changes in lung function or airway responsiveness through inappropriate timing of tests.

Although the study was intended to recreate the type of exposures that might occur in real life, it probably represents a fairly low exposure level of relatively short duration. Subjects painted only a small area using a small brush, and it is possible that painting a larger area, particularly if using a roller or spray painting, which are both likely to produce more paint aerosol, could result in higher levels of solvent and other vapours. In addition, subjects painted for only 60 min, whereas in many circumstances, particularly for professional house painters, the duration of painting will substantially exceed this time. More noticeable differences between the paints might be expected in this situation. However, we also need to take into account that the population used for this study was specifically selected to be a group likely to be sensitive to any effect from paint. All had mild-to-moderate asthma, and had previously noted a worsening of their symptoms when exposed to paint or other strong odours. Thus, the study was likely to find more symptoms and physiological changes occurring if such an effect exists.

Overall, any deterioration in these subjects' asthma was minor and related only to symptoms, and the health benefits from switching to VOC-free paint would, therefore, be relatively modest. We conclude that for most asthmatics, most of the time, neither paint would represent a substantial hazard. However, the range of response appears to be quite wide. For some people, who appear to be more sensitive than others, and for some exposures, which may be considerably higher and longer than those encountered here, exposure to paint may exacerbate asthma. Such individuals will probably derive the greatest benefits from the new volatile organic compound-free paints.

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