
Passive dispersion of latex aeroallergen in a healthcare facility

B Lauren Charous, MD*; Paul J Schuenemann, DDS†; and Mark C Swanson, BA‡

Background: Prompted by worsening asthma in a dental assistant with latex allergy and occupational asthma while under personal latex precautions, we confirmed continuing latex aeroallergen exposure.

Objectives: To determine the source of latex aeroallergen and ascertain the effects of site-wide substitution of nonpowdered low allergen latex glove in a health care site.

Methods: Using a volumetric sampler, baseline latex aeroallergen levels were measured in rooms where she worked and nearby rooms, as well as shared X-ray, laboratory, and waiting rooms. Allergen levels were measured in upholstery fabric samples, ventilation duct dust, and latex gloves. Alterations in aeroallergen levels following change of glove types were prospectively determined.

Results: Baseline latex aeroallergen levels ranged from 6 to 25 ng/m³ in the patient's work areas and in other rooms from 29 to 90 ng/m³ during work hours. Latex antigen was found in three brands of powdered latex gloves ($\bar{X}$ = 1,156 μ g/g) used in the nearby operatories and the hygiene room, and in upholstery fabric, carpet dust, but not ventilation duct dust. In the absence of any other control measures, airborne latex became undetectable (<5 ng/m³) with exclusive use of nonpowdered latex gloves.

Discussion: Latex aeroallergen is primarily generated by active glove use; carpeting and fabric upholstery can serve as important aeroallergen repositories. Site-wide substitution of nonpowdered latex gloves eliminates detectable latex aeroallergen.

Ann Allergy Asthma Immunol 2000;85:285–290.

INTRODUCTION

Natural rubber latex (NRL), commonly called “latex,” causes allergic sensitization in 5% to 17% of exposed health care workers.^{1,2} Occupational latex exposure occurs both from direct contact with latex gloves and from inhalation of latex aeroallergens carried by donning glove powders. Consequently, allergic reactions to latex include not only contact urticaria, but the full range of respiratory symptoms in-

cluding rhinoconjunctivitis, asthma, and rarely anaphylaxis.³ Occupational asthma, induced by ongoing respiration of latex allergens, affects at least 2.5% or more of exposed health care and manufacturing workers according to several recent reports.^{4–8}

Published safety recommendations for latex allergy either omit recommendations for workers with occupational asthma (Task Force on Allergic Reactions to Latex, J Allergy Clin Immunol 1993;92:16–18) or suggest that reliance on personal avoidance of latex product will provide adequate safeguard.⁹ Earlier reports have demonstrated that use of lower allergen or nonpowdered gloves has a protective effect on occupational asthma. These studies examined individual laboratories, medical center wards or surgical suites.^{10–14} Published data demonstrating the dispersion of latex aeroallergen

from areas using powdered gloves to “safe” areas containing only nonpowdered latex or nonlatex gloves” has, to our knowledge, not been previously available.

The current study was prompted by worsening asthma in a dental assistant despite adherence to personal latex avoidance measures. In brief, at an initial evaluation in July 1994, following a hospitalization for asthma, the diagnosis of latex allergy was confirmed by a non-blinded glove challenge (immersion of a gloved hand in warm water for 20 minutes) which resulted in a marked late reaction consisting of contact and facial urticaria, rhinoconjunctivitis, and symptomatic wheezing 10 minutes after the glove removal and by the finding of a latex-specific IgE level of 886 ng/ml (DACL laboratory, Johns Hopkins University). On return to clinic in October 1996, her pulmonary exam revealed a prolonged expiratory phase and spirometric flow study demonstrated marked reduction in forced vital capacity and air flows with a 25% decline in FVC and FEV₁ from her baseline despite ongoing treatment with inhaled corticosteroids. After confirming the presence of measurable latex aeroallergen in the immediate work area, she was removed from the workplace while a prospective investigation of occupational aeroallergen dispersion was undertaken and she was only allowed to return to work when latex aeroallergen levels in her work area fell below limits of detection.

The limited size of this dental practice setting, identifiable point sources of latex use, as well as a lack of forced air heating offered a unique opportunity to investigate the sources and quantitate passive dispersion of latex aerosols in a health care facility. Baseline latex aeroallergen concentrations

From *Milwaukee Medical Clinic, Advanced Healthcare, S.C., Milwaukee, Wisconsin; †Hartford, Wisconsin; and ‡Mayo Clinic and Mayo Foundation, Rochester, Minnesota.

The investigators were self-funded. Safeskin Corporation provided glove supplies, funding for laboratory assays and creation of building plans.

Received for publication December 2, 1999.

Accepted for publication in revised form May 19, 2000.

in the work areas, including other patient care areas, the laboratory, and waiting room area were measured, as well as allergen content in gloves used in each room. Alternative sources of latex aeroallergen in this building were assayed including ventilator duct, carpeting, and fabric upholstery samples. The effects of substitution of powder-free gloves on aeroallergen levels in these areas were determined. Continued unannounced use of high allergen powdered latex gloves in one dental operatory and an associated hygiene room, and later of "low-powder" latex gloves in these two rooms permitted assessment of the contribution of these types of gloves on the generation and dispersion of NRL aeroallergen.

METHODS

A volumetric area air sampler (Quan-Tec-Air, Inc., Rochester, MN) was used to collect samples over a minimum of 2 hours during or after normal office hours at a flow rate of 3 L/s from various areas of the dental office. Airborne particulates were collected onto polytetrafluoroethylene filter media (Quan-Tec-Air, Inc., Rochester, MN). The filters were extracted in 0.1 M phosphate buffer and assayed immunochemically by a competitive inhibition

technique. Latex allergens from aqueous extracts of the air filters or a standard prepared as a direct extract from gloves (Bodyguards, TK Glove Products Co, Ltd, Huntington Beach, CA) compete with immobilized latex allergens (Bodyguards) on the surface of Immunlon IV microtiter wells (Dynex, Inc., Chantilly, VA) for IgE antibodies obtained from pooled sera from seven latex sensitized individuals. These antibodies specifically identify NRL proteins which cause allergic reactions in NRL sensitive individuals. Rabbit anti-IgE radiolabeled with ^{125}I was used to detect bound IgE antibodies.¹⁵ Results represented the mean of duplicate observations and were expressed in nanograms of protein/m³ referenced by the glove extract containing 7 mg/mL of protein. The sensitivity of the assay was 5 ng, allowing detection of 100 ng in 20 m³ of air. Determination of allergen concentrations in fabric upholstery and dust were determined by 1:5 wt/vol extractions of squares of fabric or collected dust samples with phosphate buffer.

The floor plan of the dental office building is shown in Figure 1. Four dentists shared a common waiting room, X-ray and laboratory areas using an "open office" concept that provided

for doors only on storage rooms and closets. The wall separating the X-ray area from dental operatory A did not extend to the ceiling. Most rooms were non-carpeted, but the waiting room and three patient care rooms did have carpeted floors. In two, Operatories D1/D2, the carpeting was 2 years old; in a third, hygiene room B/D, the carpeting was 7 years old. Furniture with fabric upholstery was present in the waiting room, in operatory A, and in hygiene room A. The office building is heated by a hot water baseboard system. A low-flow non-filtered ventilation system that runs continuously year-round is coupled to a central air-conditioning unit during the warmer months.

Dentists B and D worked full time in the building and shared hygiene room B/D. Dentist C worked only part-time at this location averaging only 2½ days a week; his hygiene room was used only two ½ days a week. Each dental practice purchased their gloves independently (two different brands of gloves were used in hygiene room B/D). No formal records of glove change frequency were kept; these are estimated at approximately 25 to 30 per/day per employee. X-ray and laboratory areas were shared spaces, utilizing a combination of different brands of gloves. No allergen concentrations were determined for these gloves.

Baseline aeroallergen sampling was conducted December 1996 and February 1997. Allergen content was measured in powdered latex gloves used in each of dental operatories B, C, and D, and in samples of ventilation duct dust. Fabric from upholstered seats and seat backs used in hygiene room A was assayed; the covers were then replaced with vinyl upholstery. In May 1997, 1 month after presumed introduction of nonpowdered low-allergen latex gloves (Safeskin Corp, San Diego, CA) throughout the entire level, additional sampling began and continued into June 1997. Discovery of unannounced use of high-allergen latex gloves in operatory C prompted more sampling in September 1997. The effects of substituting a lightly powdered lower-allergen glove

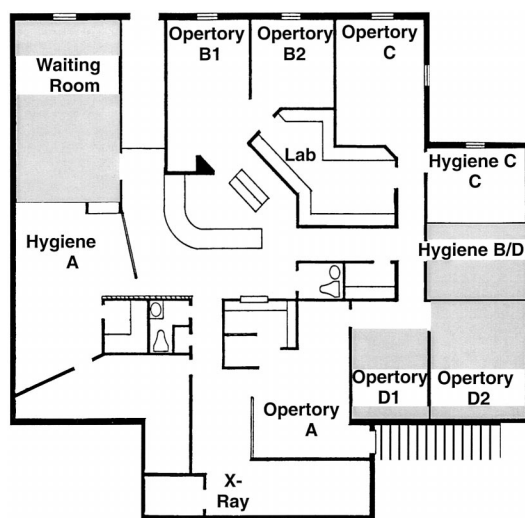


Figure 1. Blueprint of dental office building. The affected employee worked in operatory A and hygiene room A where only nonpowdered or non-latex gloves were used. Powdered latex gloves were used in all other operatories, hygiene rooms and in the lab and X-ray areas. Carpeted rooms are shaded on the figure.

(Safeskin Corp) in these areas was assessed with repeated sampling during December to January 1998. Dust samples from the carpets in Hygiene room B/D were obtained in March 1998 and again in July, 1 month after conventional steam cleaning.

RESULTS

Baseline latex aeroallergen concentrations (December to February 1997)

during work hours are shown in Figure 2A. Concentrations exceeding 10 ng/m³, believed significant based on results of prior studies,^{4,13,15,16} were obtained in the patient's work areas, despite the absence of powdered latex gloves. Measurable amounts of latex aerosol were also found in the waiting room, indicating dispersion of latex aeroallergen to nonpatient care areas as

well. In the other three dental operatories, hygiene room, X-ray area and laboratory, latex aeroallergen concentrations ranged from 12 to 90 ng/m³ during working hours. During non-work hours, latex aeroallergen was not detectable in two noncarpeted dental operatories B and C and in carpeted operatorium D1. In a room with old carpeting, hygiene room B/D, aeroaller-

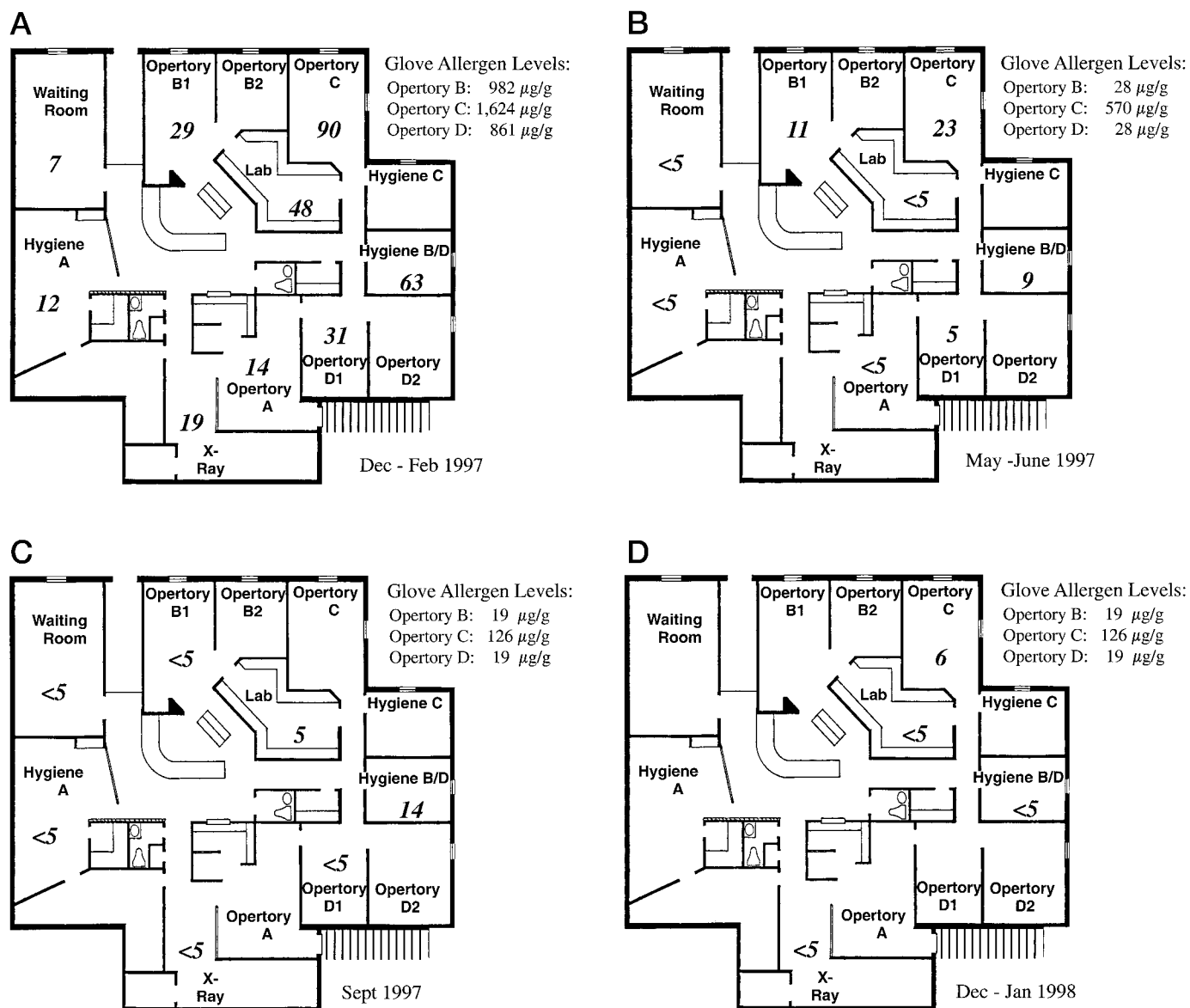


Figure 2. (A) Baseline aeroallergen levels (in *italics*). Amount of extractable glove allergen used in each operatorium noted at top right. (B) Aeroallergen levels one to two months following change to nonpowdered gloves in all areas but operatorium C. Levels in waiting room and index case work area have become undetectable. (C) Two months after conversion to lightly powdered gloves in operatorium C. Aeroallergen levels are detectable only in an adjacent lab and carpeted hygiene room. (D) Detectable levels of latex aeroallergen found only in operatorium C where "lightly" powdered gloves remain in use.

gen levels decreased 46% from working hour levels, but remained substantial (34 ng/m³) during nonwork hours.

Allergen content was determined in upholstery, ventilator duct dust and presteam and poststeam cleaning carpet dust (Table 1). Active “dusting out” of the cushions in hygiene room A, one of the rooms frequented by the worker resulted in generation of the highest aeroallergen level recorded, 370 ng/m³.

Extractable latex allergen content per gram of the gloves used are shown in Table 2. In opertory A, nonlatex gloves were used virtually exclusively. Gloves #1–3 were used by dentists B, C, and D, respectively, at baseline. Beginning April 1997, a nonpowdered low allergen glove, (glove #6) was used exclusively by dentists B and D and their employees.

Repeat sampling at least one month after introduction of nonpowdered low-allergen latex gloves (May to June 1997) demonstrated a reduction in aeroallergen concentration below the limit of assay detection in the patient’s work area (Operator and hygiene room A), in the laboratory, and in the waiting room (Fig 2B). Persistence of elevated levels of latex aeroallergen at this time, particularly in opertory C, suggested possible unannounced continued use of powdered latex gloves in this area, which was confirmed on nonscheduled site visit (Table 2, glove 4). Subsequent conversion to use of “lightly powdered” lower allergen latex gloves (Table 2, glove 5) in the fall of 1997 (September) was associated with a further reduction in latex aeroallergen concentrations. By September, only the lab (where some “lightly powdered” gloves were used) and hygiene room B/D had detectable levels (Fig 2C). Followup sampling in December,

demonstrated that measurable airborne latex was confined to areas where “lightly powdered” gloves were used (Fig 2D).

DISCUSSION

We confirmed the presence of latex aeroallergen in the work areas of this patient in quantities likely to have contributed to her occupational asthma. Since powdered latex gloves were not used in the rooms where she worked, other sources of airborne latex were investigated, including the ventilation system, dispersion from other rooms using powdered gloves, as well as possible contribution of upholstery and carpeting repositories.

The minimal amounts of latex allergen in the dust sample from the passive ventilation duct of a nonforced air heated building make this an implausible source for distribution of aeroallergens. In contrast, samples of fabric upholstery from work area chairs did contain significant amounts of latex allergen. The fact that the highest level of latex aerosol measured, 370 ng/m³ (as compared with a baseline mean of 19 ng/m³), was related to the repetitive striking of one of the seat-back cushions during a sampling period attests to the capacity of fabric upholstery to serve as a reservoir of latex allergen. Nonetheless, the persistence of measurable latex aerosols in Opertory A even after removal of fabric cushions and findings of elevated latex aerosol in other rooms where no fabric upholstery was present, suggests the primacy of another source of aeroallergen.

Our data strongly support the conclusion that utilization of powdered latex gloves is the chief source of latex aeroallergen in the medical setting. This is supported by several inter-related but independent observations. First, as seen in earlier studies, the

generation of aeroallergen appears to be dependent upon active glove use.¹⁵ During nonworking hours, when gloves were not in use, aeroallergen concentrations became undetectable in noncarpeted rooms. Second, in noncarpeted rooms where only single type of glove was in use, the concentration of aeroallergen highly correlated with the amount of extractable latex glove allergen (r = 0.9450; CI: 0.7785 to 0.9872). Third, in the absence of any other action, intervention by means of conversion to use of only nonpowdered low allergen latex gloves (glove 6) in all but two rooms, resulted in elimination of detectable latex aerosol from the patient’s work area and adjacent areas (Figs 2B,C). Fourth, elevated latex aerosol concentrations in Opertory C associated with unannounced use of powdered gloves almost completely resolved after conversion to “lightly” powdered lower allergen gloves (Fig 2D).

These observations verify that dispersion of latex aeroallergen from areas using powdered latex gloves to nonpatient care areas and to areas under “latex precautions” can occur during normal work place routines. In this nonforced air heated building, the most probable vehicle of NRL dispersion is people. The consistent finding of higher concentrations of latex aeroallergen in rooms adjacent to or nearby opertory C and hygiene B/D, suggests that passive dispersion is a factor. Whether forced air heating systems cause additional dispersion requires additional study.

As with dander antigens, carpeting and furniture serve as allergen repositories capable sustaining elevated aeroallergen concentrations even after removal of the primary source, in this case powdered gloves.^{17–21} While aeroallergen concentrations in noncarpeted rooms during nonworking hours consistently fell below detectable limits, the room with carpeting several years old, hygiene room B/D, yielded one of the highest recorded concentrations, 34 ng/m³, on a Sunday sampling. As latex aeroallergen concentrations declined throughout the floor, signifi-

Table 1. Allergen Concentrations in Upholstery, Ventilation Ducts, and Carpeting (in μg/g)

Seatcover 1	Backcover 1	Seatcover 2	Backcover 3	Ventilator Duct	Carpet Carpet	
					Dust (preclean)	Dust (postclean)
15.6	63	83.7	15.3	2	54.1	12.8

Table 2. Glove Allergen Concentrations (in $\mu\text{g/g}$)

Glove 1 Powdered Operatory B	Glove 2 Powdered Operatory C	Glove 3 Powdered Operatory D	Glove 4 Powdered Operatory C	Glove 5 Light Powder Operatory C	Glove 6 Nonpowdered
982	1624	861	570	126	19

cant concentrations persisted in hygiene room B/D (Fig 2C). This reservoir effect appears to be long-lived; carpet dust samples obtained after more than 10 months after nonpowdered glove intervention still contained notable amounts of latex allergen (Table 1). The carpeting however, only appears to retard rather than prevent aerosolization of latex. Even before carpets were cleaned, measurable aeroallergen concentrations disappeared after several months use of nonpowdered latex gloves attesting to the singular contribution of powdered latex gloves to latex aerosol as well as to the stability of latex antigen. Additional prospective studies may yield valuable information regarding the contribution of such repositories to occupational asthma in affected workers.

Baur and colleagues reported a strong association between exposure to elevated latex aeroallergen levels and the prevalence of latex allergy among exposed workers.⁴ Our study demonstrates that the relevant area of concern extends beyond the immediate work area to adjacent rooms on the same level and has important implications for both the individual worker and for institutions and employers. For workers with occupational asthma, currently recommended measures of individual protection, such as personal use of nonlatex gloves, coupled with introduction of nonpowdered latex or non-latex gloves for coworkers in the immediate area may prove inadequate. Dispersion of latex allergens from areas retaining use of powdered latex gloves, such as operating room suites and delivery rooms, to associated adjoining care areas, such as recovery and labor rooms, should be anticipated. The finding by Vandenplas and colleagues that even a substantial proportion of latex-allergic workers without a history of occupational asthma demon-

strate asthmatic reactions to specific inhalation challenge with latex gloves argues that persistent exposure to latex aeroallergen may adversely affect a appreciable number of exposed workers.²²

Based on our findings, exclusive use of nonpowdered gloves can result in virtual elimination of latex aerosol from noncarpeted rooms within one month. Cleaning of surfaces likely to serve as allergen repositories, such as carpeting, rugs, and upholstery, concomitant with introduction of nonpowdered latex gloves, seems appropriate.

Employees deserve a safe work place. Currently available powdered latex gloves have a high content of extractable latex allergen, and are the source of inhalant exposure to latex proteins. The consequent risks of allergic sensitization and exposure to workers and latex allergic patients do not justify their continued widespread usage.

ACKNOWLEDGMENTS

We thank C E Reed, MD; J W Yunginger, MD; C R Adolphson, MD; and M A Charous, PhD for their valuable suggestions.

REFERENCES

- Charous B. The puzzle of latex allergy: some answers, still more questions. *Ann Allergy* 1994;73:277-281.
- Vandenplas O, Charous B, Tarlo S. Latex Allergy. In: Bernstein D, Bernstein I, Chan-Yeung M, Malo J-L, eds. *Asthma in the workplace*. 2nd ed. New York: Marcel Dekker; 1999:425-444.
- Charous B, Hamilton R, Yunginger J. Occupational latex exposure: characteristics of contact and systemic reactions in 47 workers. *J Allergy Clin Immunol* 1994;94:12-18.
- Baur X, Chen Z, Allmers H. Can a threshold limit value for natural rubber latex airborne allergens be defined? *J Allergy Clin Immunol* 1998;101:24-27.
- Vandenplas O, Delwiche J-P, Evrard G, et al. Prevalence of occupational asthma due to latex among hospital personnel. *Am J Respir Crit Care Med* 1995;151:54-60.
- Tarlo S, Wong L, Roos J, et al. Occupational asthma caused by latex in a surgical glove manufacturing plant. *J Allergy Clin Immunol* 1990;85:626-631.
- Tarlo S, Sussman G, Holness D. Latex sensitivity in dental students and staff: a cross-sectional study. *J Allergy Clin Immunol* 1997;99:396-401.
- Zuskin E, Mustajbegovic J, Kanceljak B, et al. Respiratory function and immunological status in workers employed in a latex glove manufacturing plant. *Am J Ind Med* 1998;33:175-181.
- Charous B, Banov C, Bardana EJ, et al. Latex allergy—an emerging health-care problem. *Ann Allergy Asthma Immunol* 1995;75:19-21.
- Siu SR, Smith GJ, Sussman GL, et al. Reduction of airborne latex protein exposure by use of low protein, powder-free gloves [Abstract]. *J Allergy Clin Immunol* 1996;97:325.
- Tarlo SM, Sussman G, Contala A, et al. Control of airborne latex by use of powder-free gloves. *J Allergy Clin Immunol* 1994;93:985-989.
- Vandenplas O, Delwiche J-P, Depelchin S, et al. Latex gloves with a lower protein content reduce bronchial reactions in subjects with occupational asthma caused by latex. *Am J Respir Crit Care Med* 1995;151:887-891.
- Heilman DK, Jones RT, Swanson MC, et al. A prospective, controlled study showing that rubber gloves are the major contributor to latex aeroallergen levels in the operating room. *J Allergy Clin Immunol* 1996;98:325-330.
- Allmers H, Brehler R, Chen Z, et al. Reduction of latex aeroallergens and latex-specific IgE antibodies in sensitized workers after removal of powdered natural rubber latex gloves in a hospital. *J Allergy Clin Immunol* 1998;102:841-846.

-
15. Swanson MC, Bubak ME, Hunt LW, et al. Quantification of occupational latex aeroallergens in a medical center. *J Allergy Clin Immunol* 1994;94:445–451.
 16. Swanson MC, Yunginger JW, Reed CE. Immunochemical quantification of airborne natural rubber allergens in medical and dental office buildings. In: Maroni M, ed. *Ventilation and Indoor Air Quality in Hospitals*. The Netherlands, Kluwer Academic Publishers, 1996:257–262.
 17. Reed CE, Swanson MC, Li JT. Environmental monitoring of protein aeroallergens. In: Bernstein D, Bernstein I, Chan-Yeung M, Malo J-L, eds. *Asthma in the workplace*. 2nd ed. New York: Marcel Dekker; 1999:235–255.
 18. Beezhold D, Beck W. Surgical glove powders bind latex antigens. *Arch Surg* 1992;127:1354–1357.
 19. Karathanasis P, Cooper A, Zhou K, et al. Indirect latex contact causes urticaria/anaphylaxis. *Ann Allergy* 1993;71:526–528.
 20. Tomazic V, Shampaine E, Lamanna A, et al. Cornstarch powder on latex products is an allergen carrier. *J Allergy Clin Immunol* 1994;93:751–758.
 21. Platts-Mills T. Indoor allergens. In: Middleton EJ, Reed C, Ellis E, eds. *Allergy principles and practice*. vol. 1. St. Louis: Mosby-Year Book, Inc, 1998:393–403.
 22. Vandenplas O. Occupational asthma due to natural rubber latex. *Eur Respir J* 1995;8:1957–1965.

Request for reprints should be addressed to:
B Lauren Charous, MD
Division of Allergy/Immunology
Milwaukee Medical Clinic
3003 West Good Hope Rd
Milwaukee, WI 53209