

The prevalence of anti-latex IgE antibodies among registered nurses

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Background: Recent studies have reported that the prevalence of latex allergy among volunteer populations of health care workers ranges from 2% to 25%. To date, no epidemiologic study has investigated the prevalence of latex allergy and its relationship to possible risk factors among nurses.

Methods: Registered nurses (n = 741) in a large metropolitan hospital participated in a latex allergy prevalence study. Latex exposure data were obtained through self-administered questionnaires. Blood samples were classified as positive or negative for anti-latex IgE antibodies. Associations between potential risk factors for latex allergy and anti-latex antibodies were assessed.

Results: The participation rate was 90.6% among eligible nurses. Sixty-five samples were positive for a prevalence of 8.9% (95% confidence interval, 6.7 to 10.8). No differences in latex positivity among five nursing specialties were noted. Logistic regression indicated that after adjusting for age and sex, the following factors were significantly associated with latex seropositivity: nonwhite race (odds ratio [OR] = 4.2), reported histories of penicillin allergy (OR = 2.2), pruritic skin (OR = 2.2), conjunctivitis (OR = 3.0), localized urticaria (OR = 1.8), hay fever (OR = 2.1), avocado allergy (OR = 9.9), and ragweed allergy (OR = 3.4).

Conclusions: The prevalence of latex sensitization appeared to be substantial (8.9%) among the nurses studied, and the prevalence did not vary by nursing specialty. The factors associated with latex positivity in the logistic regression model correctly classified 81.3% of the nurses with a sensitivity and specificity of 66.7% and 82.7%, respectively. (*J Allergy Clin Immunol* 1996;98:535-44.)

Key words: Latex allergy, anti-latex IgE antibodies, prevalence, risk factor, epidemiology, nursing population

The first report of immediate hypersensitivity to natural rubber latex was published in 1979.¹ Since the U.S. Centers for Disease Control's publication of "Universal Precautions for Prevention of Viral

Abbreviations used

CI: Confidence interval
HFH: Henry Ford Hospital
OR: Odds ratio

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Transmission in the Health Care Setting" in 1987, the number of clinical reports of latex allergy has increased.² In 1988, the U.S. Food and Drug Administration began receiving reports of adverse reactions, ranging from mild hand itching to anaphylactic episodes, among health care workers using latex gloves. However, latex allergic reactions were not solely confined to health care personnel. In 1989, reports of patient deaths attributed to latex allergy among non-health care workers emerged in the medical literature.³

Studies from Canada, Finland, France, and the

United States revealed that 2% to 15% of health care personnel were allergic to latex.⁴⁻⁹ The high prevalence of IgE-mediated allergic reactions to latex in health care workers suggests that latex allergy is an occupational hazard. Independent of perilous health effects, latex allergy engenders profound economic and legal implications for both health care institutions and workers.

Registered nurses are potentially at high risk for latex allergy because of their occupational exposure to latex. To date, there have been no epidemiologic studies evaluating possible risk factors associated with anti-latex IgE antibodies among a defined population of registered nurses. This study was designed to determine the overall and specialty-specific prevalence of anti-latex IgE antibodies among registered nurses and to evaluate the associations between potential risk factors and the presence of anti-latex IgE antibodies.

METHODS

Subjects

The Latex Study among Registered Nurses is a cross-sectional study of the seroprevalence of anti-latex IgE antibodies undertaken at Henry Ford Hospital (HFH), Detroit, Michigan, among staff nurses working in the patient care delivery units. Names and demographic information for the population were provided by the hospital personnel department. Invitation letters to participate were mailed on July 7, 1993 via United States mail to all staff registered nurses ($n = 945$), employed as of May 5, 1993 (census date). During the study interval (July 21, 1993, through November 4, 1993), 741 nurses gave written consent, contributed blood for antibody testing for anti-latex IgE, and completed a questionnaire. A self-administered Latex Allergy Study Questionnaire, which could be completed in approximately 10 minutes, was used to collect exposure data. The study was approved by Henry Ford Hospital's Human Rights Committee. Confidentiality was maintained.

Potential risk factors included demographic and clinical characteristics considered potentially important in predisposing registered nurses to latex allergy. These included: age, sex, race, current nursing practice characteristics (including years actively employed as a nurse), type of glove used (latex or vinyl), frequency of glove use, and current nursing specialty (medical-surgical, emergency, labor and delivery, intensive care, or operating room nursing). A complete history was obtained: self-reported current and past symptoms associated with latex contact (including the presence of pruritus, localized urticaria, facial edema, conjunctivitis, rhinitis, shortness of breath, generalized urticaria, and cardiorespiratory arrest); self-reported allergy history, including atopic disease (hay fever, chronic sinusitis, asthma, hand and generalized eczema) and previous positive skin test responses to ragweed and mite allergens; self-reported medical history (including any current or previous food

and medication allergies, number of lifetime surgical procedures and dental visits); and respondent-reported history of biologic maternal, paternal, and sibling atopy.

Serologic assays

The serum concentration of latex-specific IgE antibodies was measured by using the AlaSTAT EIA assay (Diagnostic Products Corp., Los Angeles, Calif.). The AlaSTAT assay was performed according to the manufacturer's instructions and has been previously described in detail.¹⁰ Ten milliliters of blood was drawn for serologic testing. Each serum sample was assayed twice, and the mean IgE level was used for the analysis. Samples with anti-latex IgE antibody ≥ 0.35 IU/ml were classified as positive, and samples with IgE concentrations of 1.50 IU/ml or greater were classified as strongly positive.

Statistical analysis

Point estimates and 95% confidence intervals (CIs) for the overall prevalence of seropositivity for anti-latex IgE antibodies and the prevalence by nursing specialty were computed. The Tukey method of multiple comparisons with 95% confidence coefficients was used to test differences in anti-latex IgE antibody seropositivity prevalence by nursing specialty.¹¹

Differences in mean values of continuous variables were assessed between groups of individuals with detectable and undetectable anti-latex IgE. Nonparametric and parametric techniques were used when indicated. Categorical data were analyzed by the likelihood chi square technique with Yates' correction as indicated by the data. Fisher's exact test was used if the expected number of observations in any cell was less than 5. Odds ratios (ORs) and 95% CIs were calculated by using EPI INFO (Version 5.01a).^{12, 13} For all statistical analyses, a 0.05 level of significance was used, and all p values were two-sided.

Multiple logistic regression analysis was used to examine the relationships between a binary outcome of interest (seronegativity or seropositivity for anti-latex IgE antibodies) and multiple risk factors. This approach is widely used in epidemiologic studies because it allows simultaneous consideration of risk factors for predicting a binary outcome. Logistic regression models were fit by using the Statistical Analysis System (SAS Institute Inc., Cary, N.C.)¹⁴ with the method of maximum likelihood estimation. Logistic modeling makes it possible to choose a subset of risk factors, which best describe the relationship between these risk factors and the probability of an individual being seropositive for anti-latex IgE antibodies, given the individual's personal characteristics. Advantages of logistic multiple regression include estimating the association between risk factors and the outcome after simultaneously adjusting for a number of potentially confounding factors. In addition, ORs, representing the magnitude of the association between the anti-latex IgE antibody state and risk factors, can also be calculated from the coefficients of the binary independent variables while controlling for the effects of other predictor variables in the model. ORs and 95%

CIs were obtained from maximum likelihood parameter estimates. The proportion correctly classified as seropositive or seronegative for anti-latex IgE by using the final logistic model was evaluated by cross-tabulating the true number of positive and negative samples observed with the number of positive and negative samples predicted by this model with a 0.10 probability. We chose a conservative probability level (0.10) on the basis of previously reported studies suggesting that 10% was a reasonable estimate for latex allergy risk among nurses.⁴⁻⁹ Therefore if the logistic model predicts the probability of an individual being seropositive for anti-latex IgE antibodies as 0.10 or higher, then that individual would be classified as seropositive for anti-latex IgE antibodies. Otherwise, that individual would be classified as negative. See the appendix for details.

Not all possible risk factors were eligible for inclusion in the multiple regression model. Selection of risk factors for the multiple logistic regression was based on: (1) empirical knowledge obtained through published case reports and prevalence studies, (2) physiologic plausibility, and (3) *p* values of 0.15 or less from the unadjusted associations between risk factors and seropositivity. A *p* value of 0.15 from the unadjusted analyses was chosen to reduce the risk of excluding a factor that might be more significant after controlling for the effects of other factors.¹⁵

On the basis of the preliminary unadjusted analysis, candidate factors were initially grouped into the following covariate categories and considered for inclusion in the overall model: personal history of atopy, skin test responses to inhalant allergens, clinical manifestations associated with latex contact, food allergies, and penicillin allergy. For each covariate category, a separate model was run to determine the best risk factor or factors for the category.

The final multivariate logistic model was obtained by using a combination of two methods. The change-in-estimate procedures, suggested by Mickey and Greenland,¹⁵ were used to select strong risk factors on the basis of a 15% change in the OR in the estimated exposure effect. Likelihood ratio for chi square tests was also used to test the significance of the different risk factors and fit of each logistic model.^{14, 17} These methods helped to ensure that the final model provided maximum predictive value with the fewest number of factors. Interactions were assessed. No interactions were found to be significant, and thus none were included in the final model. The final overall multivariate model was considered significant at the 0.05 level.

RESULTS

Study population

Of the initial population selected for the study (*n* = 945), 818 nurses (86.6%) were eligible to participate. Reasons for being considered ineligible included termination of employment (*n* = 82), leave of absence (*n* = 33), a non-latex-related death (*n* = 1) after starting enrollment, and job

title misclassification (*n* = 11). During the 4-month enrollment period, 741 nurses enrolled in the study for an overall participation rate of 90.6%. No difference in participation rate by nursing specialty was detected.

To determine whether the results of this study may have been subject to participation bias, the characteristics of participants were compared with those of nonparticipants. Differences in age and length of time (years) employed as a nurse at HFH were not significant. Among the 741 participants, the mean age was 36.0 years (standard deviation, 8.1 years; range, 21 to 62 years), and the mean length of time employed as a registered nurse at HFH was 8.9 years (standard deviation, 7.2 years; range, 4 months to 40 years).

The data indicated an overrepresentation of participating white nurses compared with non-white nurses (72.2% vs 57.1%; *p* ≤ 0.05) and participating female nurses compared with male nurses (92.3% vs 84.4%; *p* ≤ 0.05). Of the non-white sample population (*n* = 206), the majority were African-American (*n* = 127), with the remaining population being Asian (*n* = 67), Native American (*n* = 6), Hispanic (*n* = 3), and other (*n* = 4). Among participants, 684 (92%) were female.

Prevalence of anti-latex IgE antibodies

Sixty-five of the nurses were positive for anti-latex IgE antibodies for a prevalence of 8.9% (95% CI, 6.7 to 10.8). Samples from 27 nurses were strongly positive for a prevalence of 3.6% (95% CI, 2.3 to 5.0).

The prevalence and 95% CIs of seropositivity for anti-latex IgE by nursing specialty are shown in Fig. 1. Although the prevalence among specialties ranged from 6.4% for operating room nurses to 13.6% for labor and delivery nurses, there was no overall difference in the proportion of positive samples. Using the Tukey multiple comparison technique, no differences in the proportion of positive samples were noted between any combination of the five nursing specialty divisions: medical-surgical, emergency, labor and delivery, intensive care, and operating room. There were also no differences in the prevalence of strongly positive samples of anti-latex IgE between any combination of nursing specialties; among specialties, 4.4% (*n* = 11) of the medical-surgical nurses were strongly positive for anti-latex IgE antibodies as were 4.1% (*n* = 10) of the intensive care nurses, 2.3% (*n* = 3) of the operating room nurses, 3.0% (*n* = 2) of the emergency department nurses, and 4.5% (*n* = 1) of the labor and delivery nurses.

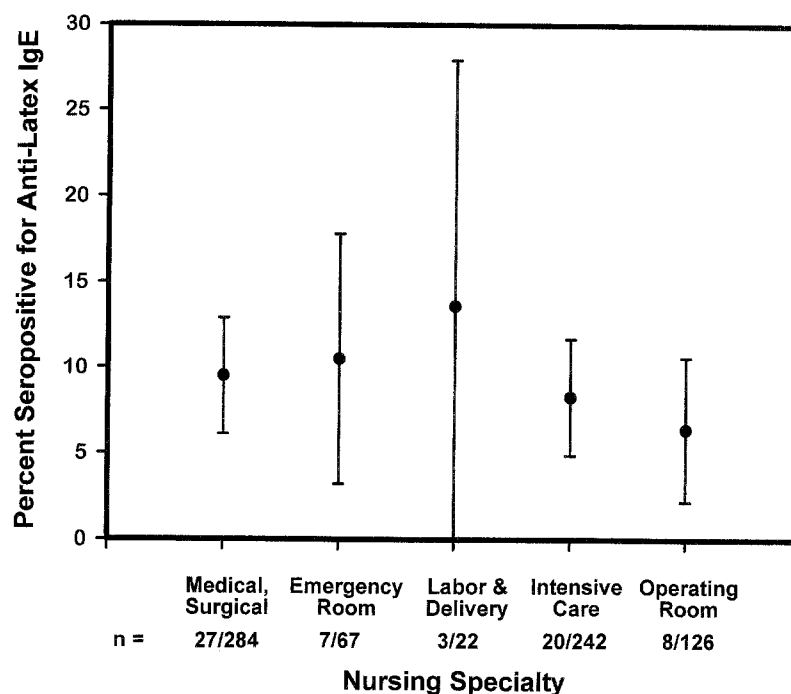


FIG. 1. Point prevalence and 95% CIs of latex allergy by nursing specialty among registered nurses at HFH in Detroit, July 21, 1993 through November 4, 1993 ($n = 741$).

Analysis of potential risk factors

Table I presents the unadjusted ORs for selected potential risk factors for seropositivity for anti-latex IgE antibodies. Although the prevalence of positive serum samples was not significantly associated with age, years of employment at HFH, or sex, a higher prevalence of positive samples was observed among nonwhite nurses compared with white nurses (14.6% vs 6.5%; $p \leq 0.001$), resulting in an OR of 2.4 (Table I).

Nurses reporting at least one symptom associated with latex contact were 4.5 times more likely to be seropositive for anti-latex IgE antibodies than nurses reporting no symptoms (95% CI, 2.1 to 9.9; $p \leq 0.001$) (Table I). Although all of the latex allergy-related symptoms were significantly associated with anti-latex IgE seropositivity, facial edema was the latex-associated symptom with the greatest OR (26.3) for anti-latex IgE. However, not all nurses who were seropositive for anti-latex IgE antibodies reported physical symptoms associated with latex contact and vice versa. Although 86.2% of nurses who were seropositive for anti-latex IgE reported at least one symptom associated with latex allergy, 58.0% of nurses who were seronegative for anti-latex IgE also reported at least one symptom suggestive of allergy after latex contact.

Compared with nurses who had no personal history of atopic disease, nurses reporting at least one atopic disease had at least three times higher probability of having anti-latex IgE antibodies (Table I). Samples from nurses with specific atopic disease histories were also more likely to be positive for anti-latex IgE than samples from nurses with negative histories of the specific disease: hay fever (50.7% vs 21.1%; $p \leq 0.001$), asthma (17.0% vs 9.0%; $p \leq 0.05$), and hand eczema (21.5% vs 8.4%; $p \leq 0.001$). Participants reporting at least one positive skin test response to an inhalant allergen, compared with nurses reporting negative skin test responses and nurses who were never skin tested, were significantly more likely to be seropositive for anti-latex IgE. The ORs for anti-latex IgE, given positive ragweed and mite skin test responses, were 4.9 (95% CI, 2.6 to 2.9; $p \leq 0.001$) and 3.7 (95% CI, 1.8 to 7.3; $p \leq 0.001$), respectively (data not shown).

Nurses reporting certain food allergies were more likely to have positive anti-latex IgE test results, including banana allergy (6.1% vs 1.8%; $p \leq 0.05$), avocado allergy (4.6% vs 0.4%; $p \leq 0.01$), peanut allergy (4.6% vs 1.2%; $p \leq 0.05$), and tree nut allergy (6.2% vs 1.5%; $p \leq 0.01$). No statistically significant association was noted be-

TABLE 1. Odds ratios of possible risk factors and the prevalence of anti-latex IgE

Factor	No. of nurses (%)	Unadjusted OR (95% CI)*	p Value
Demographic variables			
Female sex	684 (92.0)	1.0 (0.3-2.6)	NS
Nonwhite race	206 (27.8)	2.4 (1.4-4.1)	≤0.001
Symptoms associated with latex exposure†			
At least 1 symptom	448 (60.4)	4.5 (2.1-9.9)	≤0.001
Pruritus	423 (57.1)	4.4 (2.1-9.8)	≤0.001
Localized hives	107 (14.4)	8.2 (3.4-20.0)	≤0.001
Conjunctivitis	96 (13.0)	10.5 (4.4-25.6)	≤0.001
Facial edema	11 (1.5)	26.3 (5.1-123.1)	≤0.001
Rhinitis	99 (13.4)	8.0 (3.3-19.8)	≤0.001
Dyspnea	27 (3.6)	11.0 (3.3-37.0)	≤0.001
Generalized hives	14 (1.9)	17.5 (3.7-72.7)	≤0.001
History of atopic disease‡			
At least 1 disease	287 (38.7)	3.0 (1.7-5.2)	≤0.001
Hay fever	176 (23.8)	3.8 (2.2-6.7)	≤0.001
Asthma	72 (9.7)	2.1 (1.0-4.3)	≤0.05
Hand eczema	71 (9.6)	3.0 (1.5-6.0)	≤0.001
Food Allergies‡§			
At least 1 allergy	16 (2.2)	2.9 (1.3-6.7)	≤0.01
Banana allergy	16 (2.2)	3.5 (1.1-11.2)	≤0.05
Avocado allergy	6 (0.8)	10.9 (2.2-55.3)	≤0.01
Peanut allergy	11 (1.5)	4.5 (1.0-15.6)	≤0.05
Treenut allergy	14 (1.9)	4.4 (1.3-14.3)	≤0.01
Kiwi allergy	16 (2.1)	1.5 (0.2-6.8)	NS

NS, Not significant.

*OR of possible risk factors for seropositivity to anti-latex IgE antibodies among registered nurses.

†ORs are relative to nurses who did not report any symptoms.

‡Potential risk variables are dichotomized (yes vs no).

§Nurses never trying specific foods were excluded from univariate analyses: avocados ($n = 7$), peanuts ($n = 1$), tree nuts ($n = 3$), and kiwi ($n = 6$).

||Includes participants with at least one of the following reported allergies: banana, avocado, peanut, tree nut or kiwi.

tween kiwi allergy and anti-latex IgE antibodies (OR, 1.5; 95% CI, 0.2 to 6.8).

A reported history of allergy to penicillin appeared to be related to anti-latex IgE (OR, 2.6; 95% CI, 1.3 to 5.1; $p \leq 0.001$) (data not shown). The prevalence of positive anti-latex IgE test results was not associated with the number of lifetime surgical procedures or dental visits. When data concerning family history of atopic diseases were analyzed, the association between sibling history of asthma and seropositivity of anti-latex IgE antibodies (data not shown) reached borderline significance (OR, 1.9; 95% CI, 0.9 to 3.7; $p \leq 0.05$).

Potential risk factors concerning the frequency and amount of glove use were considered to be internally inconsistent and hence are not shown or used in the logistic regression. We believed that nurses who experienced any adverse reaction to latex gloves were more likely to have switched to

nonlatex gloves. Such behavioral changes would confound any relationship between current exposure to latex gloves and the presence of anti-latex IgE antibodies. Among nurses reporting use of gloves on a daily basis ($n = 727$), 67.5% used only latex gloves, 3.3% used only vinyl gloves, and 29.2% used both latex and vinyl gloves. Nurses exclusively using vinyl or other brands of nonlatex gloves were 8.5 times more likely to have positive samples for anti-latex IgE than nurses using only latex gloves (95% CI, 3.5 to 20.5; $p \leq 0.01$). More positive samples were found among nurses using only vinyl gloves compared with nurses using only latex gloves (41.6% vs 7.7%; $p \leq 0.001$). Among serum samples positive for anti-latex IgE, 7.8% of the samples were from nurses using latex gloves daily as opposed to 26.3% of the samples from nurses using any brand of nonlatex gloves daily (OR, 0.2; $p \leq 0.001$).

The final multivariate model for seropositivity

TABLE II. Results of multivariable logistic regression analysis for seropositivity for anti-latex IgE antibodies*

Factor	Parameter estimate	Standard error	Adjusted OR and 95% CI		p Value
Intercept	-3.884	0.918			
Age	-0.005	0.020			NS
Female sex	-0.461	0.543	0.6	0.2-1.8	NS
Nonwhite race	1.426	0.325	4.2	2.2-7.9	≤0.001
Penicillin allergy	0.768	0.382	2.2	1.2-4.6	≤0.05
Pruritic skin	0.809	0.377	2.2	1.1-4.7	≤0.05
Conjunctivitis	1.108	0.344	3.0	1.5-5.9	≤0.01
Localized urticaria	0.612	0.361	1.8	1.0-3.7	0.08
Hay fever	0.736	0.344	2.1	1.1-4.4	≤0.05
Avocado allergy	2.289	0.957	9.9	1.5-64.4	≤0.05
Positive ragweed skin test result	1.220	0.393	3.4	1.6-7.3	≤0.01

NS, Not significant.

*Results are adjusted for all factors in the table. The likelihood ratio statistic for the multiple logistic model was 93.9 with 10 degrees of freedom ($p \leq 0.001$).

for anti-latex IgE antibodies is presented in Table II. Although minimal differences in the ORs were noted with and without inclusion of age and sex in the model, age and sex were included in the logistic model as a conservative approach because little is known about the potential confounding effects of these two variables. The low percentage of male participants made the utility of sex as a confounder less easy to assess.

The adjusted ORs for each factor in the logistic model tended to be smaller in magnitude compared with unadjusted ORs shown in Table I, except for race, which almost doubled in magnitude (2.4 to 4.2). The greatest reductions in magnitude were observed among the symptoms associated with latex contact. The OR decreased for pruritus by 50%; for conjunctivitis, by 71.4%; and for localized urticaria, by 78%. A history of systemic adverse reactions to latex exposure was not related to the presence of anti-latex IgE antibodies in the multivariate model, probably because of the low prevalence of these symptoms.

The final model in Table II appeared to be the most parsimonious and best-fitting model for the data on the basis of the magnitude of its log likelihood. This model included age, sex, nonwhite race, reported histories of penicillin allergy, pruritic skin, conjunctivitis, localized urticaria, hay fever, avocado allergy, and ragweed allergy (chi square for the log likelihood was 93.9; 10 degrees of freedom; $p \leq 0.001$). Inclusion of glove type (vinyl gloves vs all nonvinyl gloves) in the model reduced the goodness-of-fit and did not have any significant effect on the log likelihood of the

model. These values are based on a 10% cutpoint; that is, a nurse was classified as anti-latex IgE positive if the model predicted anti-latex IgE positivity with a probability of 10% or greater. The results also indicated (data not shown) that the final logistic model correctly classified 81.3% of the nurses with a sensitivity of 66.7% and a specificity of 82.7%.

DISCUSSION

The prevalence of anti-latex IgE antibodies was 8.9% in the 741 registered nurses studied. This prevalence is consistent with previous reports of 2.2% to 15.4% prevalence of latex sensitivity among nurses.⁴⁻⁹ The factors that were most closely associated with the presence of anti-latex IgE were nonwhite race; self-reported allergy to penicillin; pruritus, conjunctivitis, and localized urticaria on latex exposure; a history of hay fever; and allergies to avocado or ragweed.

Contrary to data from Turjanmaa,⁴ suggesting that operating room nurses are almost five times more likely to be allergic to latex than non-operating room nurses, operating room nurses in our institution did not have a significantly higher prevalence of anti-latex IgE antibodies than non-operating room nurses. A possible explanation for this disparity is the lack of a predefined population in the study by Turjanmaa.⁴ Her study included only operating room nurses who volunteered. Because those who volunteered may have believed that they had latex allergy, the estimated prevalence of latex allergy may have been falsely elevated. This discrepancy may also reflect the healthy worker phe-

nomenon. Nurses allergic to latex may have been more likely to transfer out of the operating room to other nursing departments than nurses not allergic to latex, resulting in fewer latex-sensitive operating room nurses in our study. Unfortunately, we did not obtain long-term employment histories to allow us to analyze for this phenomenon. The insignificant differences in anti-latex IgE prevalence between nursing groups may also be a function of insufficient sample size in each nursing specialty group, resulting in reduced statistical power to detect differences, although the range of percentages across specialties was not large (6.4% to 13.6%).

Biologic mechanisms responsible for associations between latex allergy and possible risk factors require further investigation. The different proportions of detectable anti-latex IgE between the sexes may be due to hormonal influences; however, an analysis of this hypothesis would require a larger sample of male participants. The independent association between race and latex allergy has not been previously reported, and there is no current biologic evidence to explain the increased prevalence of positive samples among nonwhite subjects compared with white subjects. The difference in the prevalence between the races may perhaps be attributed to biologic, physiologic, or environmental factors.

Our data confirm the previously reported associations between banana, avocado, and latex allergy; previous studies have suggested that common allergens exist between banana, avocado, and latex.¹⁸⁻²³ Associations between anti-latex IgE and adverse reactions to other foods were not significant after controlling for other risk factors. The lack of significant associations with other foods is probably a function of the low prevalence of reported food reactions. Additionally, insufficient food allergy data in previously reported studies precluded the ability to analytically assess the relationships between specific food allergies and latex allergy.

Our study had several important strengths. This study was the first to systematically enroll a defined group of health care workers, thereby decreasing the potential for volunteer bias, in contrast to previous studies, which only recruited volunteer subjects.^{4-9, 24, 25} Because volunteers tend to be more attentive to their health and because individuals with symptoms are more likely to volunteer, prevalence estimates in other studies may have been spuriously inflated.

The high response rate (90.6%) is also a strength

of this study. All participating nurses in this study completed questionnaires and donated blood samples. This study has the highest reported participation rate of any study assessing the prevalence of latex allergy among defined populations of health care workers.⁴⁻⁹ Lagier et al.⁶ reported a response rate of 73.5%, which only included participants willing to complete a questionnaire and agreeing to skin prick testing. Our ability to assess the representativeness of our sample population was enhanced by obtaining demographic data concerning nonparticipants, as well as participants, unlike previously published reports.

We used an *in vitro* assay to detect anti-latex IgE antibodies. Although skin prick testing may appear to be a more sensitive test, especially when two or more latex source materials are used in the extract,^{26, 27} there is no standardized commercial extract available in the United States. Logistically, it was not possible to perform skin testing as part of this study. The latex reagent used in the AlaSTAT EIA assay was approved by the Food and Drug Administration during the course of this study. As part of the Food and Drug Administration evaluation, the stability of the latex antigens bound to carrier molecules was demonstrated. In a previous study the AlaSTAT assay was highly sensitive.¹⁰ *In vitro* tests offered objectivity and increased safety while decreasing the time required for testing as compared with *in vivo* tests.

The large sample size allowed us to determine the relationships between many potential risk factors and the presence of anti-latex IgE antibodies. To date, no latex allergy prevalence study has assessed such a variety of risk factors.^{4-9, 24, 25} Unlike other investigators, we were able to develop a multivariate logistic model predicting the presence of anti-latex IgE antibodies.

This study demonstrated that current use of latex gloves was not positively associated with seropositivity to anti-latex IgE. This suggests that an increase in nonlatex glove use parallels the emerging recognition of latex allergy since 1987. As behavior modification continues, it will be increasingly difficult to accurately study the relationship between glove use and latex allergy. Unfortunately, it was impossible to accurately estimate the allergen content of gloves used by nurses because most nurses could not recall the specific brands they used in the institution before and during the study period. Similarly, it was impossible to estimate the relative allergen exposure from examination gloves compared with surgical gloves.

Recall bias is a major limitation of this study. Frequency and type of glove use since 1987 were not assessed because it was evident in the pilot studies that nurses could not recall such detailed information. Self-reported atopic disease and specific allergen skin test results are other limitations. Because of time and economic limitations, it was not possible to verify responses with medical records, and it was not feasible to reproduce skin testing with other allergens as part of this study.

Self-selection bias, despite the high participation rate, is another potential limitation of the study. We did not blind the purpose of the study because we believed that the time constraints of working nurses would halter participation if the objective had not been disclosed. Our study population may also be biased in relation to the degree of latex exposure or the propensity to allergic disease, but we could not evaluate these factors. Self-selection bias is not unique to this study because volunteer populations have been used in previous latex allergy prevalence studies.^{4-9, 24, 25} Potential recall bias and the overrepresentation of white subjects and women were other limitations of this study. Additionally, nurses allergic to latex may have been more likely to leave the hospital environment or transfer to non-patient care positions.

Data acquired in this prevalence study provide the foundation for obtaining latex allergy incident data among this nursing population. By prospectively monitoring nurses who are seronegative for anti-latex IgE antibodies, incident data can be obtained to determine risk factors for the development of latex allergy.

Although multiple historical factors were related to the prevalence of having anti-latex IgE antibodies, the ability to predict the prevalence of anti-latex IgE antibodies was limited. Although the logistic model presented in this study classified 81.3% of the observations correctly, the model is only moderately sensitive. This suggests that historical information is of limited value for predicting latex sensitization. If it is important to ascertain latex sensitivity, direct testing appears necessary.

In conclusion, 8.9% of staff nurses were seropositive for anti-latex IgE antibodies, regardless of the type of nursing unit in which they worked or length of employment. This suggests that latex allergy is an occupational hazard of nursing and, presumably, any form of health care work requiring regular barrier protection with latex products. Given the ubiquity of latex products such as condoms,

cervical caps, and household rubber gloves, latex allergy is surfacing as a health concern among the general population. A recent study revealed that 6.4% of Red Cross blood donors were seropositive for anti-latex IgE antibodies.²⁸ The high prevalence of latex sensitivity in nurses and the potential economic consequences suggest the need for methods to reduce latex sensitization. Because the elimination of latex products is currently neither economically nor technically feasible, other methods may be needed to reduce the risk. Potential methods of reducing risk include lowering the allergen content of latex products, substituting nonlatex products when possible, and reducing airborne latex exposure.

A copy of the Latex Allergy Study Questionnaire may be obtained on request.

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APPENDIX

A multiple logistic regression model¹⁶ was used to describe the relationship between the binary outcome (being seropositive vs seronegative for anti-latex IgE antibodies) and a set of risk factors. The predicted probability ($\hat{P}$) obtained from a logistic regression model in this study is the estimated probability that a specific registered nurse is seropositive for anti-latex IgE antibodies. The logistic model is designed to describe a probability, which is expressed as a number bounded by 0 and 1. For example, a probability estimate of 0.10 represents a 10% probability of being seropositive, given the values of the risk factors included in the model. A logistic model predicting the probability of being seropositive for anti-latex IgE antibodies was fit to the data by the method of maximum likelihood estimation by using SAS.¹⁴

The logistic model of the probability of being seropositive for anti-latex IgE antibodies, given the risk factors is:

$$\text{Probability} = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k)}}$$

where e is the base of the natural logarithm, the β s ($\beta_0, \dots, \beta_k$) represent the regression coefficients, and the X s ($X_1, \dots, X_k$) represent the values of the risk factors included in the model. A specific β is tested to determine whether it is significantly different from zero on the basis of the likelihood ratio criterion. Because the model allows the inclusion of multiple risk factors simultaneously, the association between a binary outcome and a specific risk factor can be estimated, adjusting for possible confounding effects of the other risk factors in the model. In addition, the OR can be estimated from the coefficients of the fitted model (i.e., $\widehat{OR}_1 = e(\hat{\beta}_1)$) as a measure of the association between the outcome and a specific risk factor.

A probability cutoff point is used to classify an observation as being seropositive or seronegative in this study. By specifying a probability cutoff point, the predicted allergic status can be compared with the actual allergic status, which provides a measure of the predictive accuracy of the model. A cutoff point is specified before applying the predictive equation (a priori). For example, for the model described in Table II, a cutoff point probability value of 0.10 is used to classify a specific registered nurse as seropositive or seronegative for anti-latex IgE antibodies. On the basis of previous studies of latex allergy, a 10% prevalence was a reasonable expectation.⁴⁻⁹ Therefore individuals with estimated probabilities calculated from the logistic equation of 0.10 or greater were predicted to be seropositive, and individuals with estimated probabilities of less than 0.10 were predicted to be seronegative for anti-latex IgE antibodies.

Described below is a hypothetical application of the logistic regression model to calculate the predicted probability of a registered nurse being seropositive, given values for the risk factors (age, sex, race, penicillin allergy, pruritic skin, conjunctivitis, localized urticaria, hay fever, avocado allergy, and positive response to skin testing with ragweed). The risk factor values need to be substituted into the formula for the fitted model to compute the estimated probability of the nurse being seropositive for anti-latex IgE antibodies:

$$\begin{aligned}\hat{P} = 1/1 + 3 e^{-(\hat{\beta}_0 + \hat{\beta}_1 X_{age} + \hat{\beta}_2 X_{sex} + \\ \hat{\beta}_3 X_{penicillin\ allergy\ (yes/no)} + \hat{\beta}_4 X_{pruritic\ skin\ (yes/no)} + \\ \hat{\beta}_5 X_{conjunctivitis\ (yes/no)} + \hat{\beta}_6 X_{localized\ urticaria\ (yes/no)} + \\ \hat{\beta}_7 X_{hay\ fever\ (yes/no)} + \hat{\beta}_8 X_{avocado\ allergy\ (yes/no)} + \\ \hat{\beta}_9 X_{positive\ ragweed\ skin\ test\ (yes/no)})}\end{aligned}$$

To illustrate the calculation of a predicted probability, consider a nurse with the following characteristics: 45 years old; female; African-American; a negative history of penicillin allergy; a positive history of pruritic skin, conjunctivitis, localized urticaria, and hay fever; a negative history of avocado allergy; and a negative response to skin testing with ragweed. If zero represents male gen-

der, white race, and the absence of the remaining exposure variables and one represents female gender, nonwhite race, and the presence of the remaining exposure variables, the predicted probability is 0.5302:

$$\begin{aligned}\hat{P} = 1/1 + e^{-(1(-3.884 + 45(-0.005) + 1(-0.461) + \\ 1(1.426) + 0(0.768) + 1(0.809) + 1(1.108) + 1(0.612) + \\ 1(0.736) + 0(2.289) + 0(1.22))}\end{aligned}$$

Because the predicted probability of 0.5302 is greater than the a priori cutoff point probability of 0.10, this registered nurse would be classified as being seropositive for anti-latex IgE antibodies.

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