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(54) Title: PROGNOSTIC ALLERGY OR INFLAMMATION TEST

(57) Abstract

One can predict the likelihood a child will outgrow an allergy, especially a food allergy, by screening for IgE antibodies immunoreactivities with linear versus conformational epitopes. The child is first screened using standard techniques to determine what antigens the child is allergic to. The immunoglobulins in the sample from the patient are then characterised either using the natural purified antigen, recombinant antigen, reduced and alkylated antigen, proteolytic fragments of the antigen or synthetic peptides of between 4 and 40 amino acids in length, which can be immobilised for rapid and accurate screening. The antibodies from the patient are reacted with the protein or peptides to determine which peptides are bound by the antibodies. These antibodies are then characterised to determine if the epitopes they bind are linear or conformational. Those patients having antibodies primarily reactive with conformational epitopes will typically outgrow their allergies. A similar method for evaluation of IgG antibodies can be used to predict the prognosis of certain inflammatory disorders.

PROGNOSTIC ALLERGY OR INFLAMMATION TEST

Background of the Invention

The United States government has certain rights in this invention by virtue of grants AI24439 from the NIAID and RR00052 from the DRR, National Institutes of Health.

This application claims priority to U.S. Serial No. 60/073,171 filed January 30, 1998.

Hypersensitivity reactions to foods affect up to 6% of children in the first few years of life (Bock, S.A. 1987. *Pediatrics* 79:683-688), with milk, egg, and peanut accounting for most of the documented allergic responses (James JM and Sampson HA. 1992. *Pediatr Allergy & Immunol* 3:67-78). Most milk-allergic children develop cow milk hypersensitivity in the first year of life and then approximately 80% "outgrow" their reactivity (i.e. become clinically tolerant) by three years of age (Host, A. 1994. *Pediatr Allergy Immunol* 5:5-36). Hypersensitivity to hen's egg and peanut are more often recognized in the second year of life. Egg allergy appears to be more persistent than cow milk allergy whereas peanut allergy is very rarely "outgrown" (Bock, S.A. 1982. *J Allergy Clin Immunol* 69:173-17; Sampson, H.A. and S.M. Scanlon. 1989. *J Pediatr* 115:23-27; Bock, S.A. and F.M. Atkins. 1989. *J Allergy Clin Immunol* 83:900-904). The basis for these differences in persistence of clinical hypersensitivity to different food allergens is unknown.

Egg allergy is present in nearly two-thirds of children with atopic dermatitis (Sampson, H.A. J. 1997 *Roy. Soc. Med.* 90(suppl 30):3-9). When egg allergic children are placed on a diet devoid of all egg protein, about one-third develop clinical tolerance to egg within 2 years, even though IgE antibodies to egg (e.g. positive prick skin tests) persist for several years (Sampson 1989). Ovomucoid (*Gal d* 1) is the dominant allergen in hen's egg, and children with persistent egg allergy have significantly higher concentrations of IgE anti-ovomucoid antibodies than those who "outgrow"

their reactivity (Bernhisel-Broadbent, J.,et al. 1994. *J Allergy Clin Immunol* 93:1047-1059). Ovomucoid is a glycoprotein comprised of 186 amino acids arranged in three tandem domains containing nine intra-domain disulfide bonds and five carbohydrate side chains (Kato, et al.1987. *Biochemistry* 26:193-201).

It is an object of this invention to provide an assay including methods and reagents for predicting the likelihood that children will outgrow an allergy, especially a food allergy.

It is a further object of the present invention to provide a method and reagents to screen for the presence of antibodies to linear versus conformational epitopes in patient samples.

It is still another object of the present invention to provide a method and reagents to screen patients with inflammatory bowel disease to determine the likelihood they will have a more progressive, refractory course.

Summary of the Invention

Methods and reagents are provided for use in predicting the likelihood a child will outgrow an allergy, especially a food allergy, by screening for the immunoreactivity of IgE antibodies with linear epitopes as compared to conformational epitopes. The child is first screened using standard techniques to determine what antigens the child is allergic to. The immunoglobulins in the sample from the patient are then characterized either using the natural purified antigen, recombinant antigen, reduced and alkylated antigen, proteolytic fragments of the antigen or synthetic peptides of between four and 40 amino acids in length, preferably six to ten amino acids, which can be immobilized for rapid and accurate screening. The antibodies from the patient, typically present in a serum or plasma sample, are reacted with the protein or peptides to determine which peptides are bound by the antibodies. These antibodies are then characterized to determine if the epitopes they bind are linear or conformational. Those

patients having antibodies primarily reactive with conformational epitopes (that is, reactive with native protein or proteolytic fragments, as compared to reduced and alkylated protein or synthetic linear peptides) will typically outgrow their allergies. Those that are reactive primarily with linear epitopes may not outgrow their reactivity and may need to be treated to induce tolerance.

The method for screening is demonstrated in an example utilizing pooled sera from egg-allergic patients and overlapping synthetic decapeptides derived from the sequence for ovomucoid. Ovomucoid was found to possess five allergenic IgE-binding epitopes. Evaluating allergenic epitopes with individual patient sera revealed three patterns of epitope binding: extensive IgE binding to decapeptides in all three ovomucoid domains, IgE binding predominantly to peptides in the first domain, and virtually no IgE binding to any synthetic peptides, indicating that most IgE antibodies in the latter group recognized conformational epitopes. All patients had extensive IgG antibody binding to the linear, synthetic peptides whereas all non-egg allergic controls recognized only conformational epitopes. Patients in the group with extensive IgE binding to linear decapeptides tended to be older and have more severe, generalized allergic symptoms following egg ingestion than the patient group with little IgE antibody to synthetic peptides. These findings indicate that differential antigen processing and antibody-epitope structural recognition play a role in the clinical course of allergen sensitivity.

A similar method for evaluation of IgG or IgA antibodies can be used to predict the prognosis of certain inflammatory disorders, especially those involving the gastrointestinal tract such as Crohn's disease, ulcerative colitis, and celiac disease.

Brief Description of the Drawings

Figure 1. Cumulative SPOTs IgE *Gal d* 1 OD scores for each of the 89 overlapping synthetic decapeptides generated on the SPOTs membrane. Scores reflect total binding of the 17 egg allergic patients studied.

Figure 2. Cumulative SPOTs IgG *Gal d* 1 OD scores for each of the 89 overlapping synthetic decapeptides generated on the SPOTs membrane. Scores reflect total binding of the 17 egg allergic patients studied.

Figures 3a-c. Patterns of ovomucoid-specific IgE binding to synthesized decapeptides, shown as median cumulative SPOTs IgE *Gal d* 1 OD scores: Group 1; Figure 3a, possessed IgE antibodies to epitopes in all three ovomucoid domains, Group 2, Figure 3b, had ovomucoid-specific IgE antibodies primarily to epitopes in the first ovomucoid domain, and Group 3, Figure 3c, had negligible IgE antibodies to any synthetic decapeptides.

Figures 4a-e. Median cumulative SPOTs IgG *Gal d* 1 OD scores, egg-allergic patients (Figures 4a - 4c) and non-egg-allergic controls:atopic dermatitis patients without egg allergy (Figure 4d) and non-allergic normal controls (Figure 4e).

Figures 5a-b. The ratio of ovomucoid-specific IgE (Figure 5a) and IgG (Figure 5b) antibodies to native and "linearized" (reduced and alkylated) ovomucoid were compared for each egg allergic patient group.

Detailed Description of the Invention

In the generation of IgE-specific antibodies, B cells are activated following surface-IgM binding to exposed oligopeptides on the native protein. Consequent IgE antibodies produced may be directed at *linear epitopes* which represent 8 - 20 consecutive (sequential) amino acids or *conformational epitopes* which are comprised of amino acid residues from different regions of the allergen. Both linear (e.g. *Phl p* 1; timothy grass (Ball, et al.1994. *J Biol Chem* 269:28232-28242)) and conformational (*Bet v* 1; birch pollen (Laffer, et al. 1996. *J Immunol* 157:4953-4962)) B cell epitopes have been defined to inhaled aeroallergens, although the latter are presumed to predominate. Since food allergens are subjected to extensive chemical and proteolytic digestion prior to absorption and uptake by cells of the gut-associated lymphoid tissue, it has been inferred that food allergenic epitopes are predominantly linear in nature. However, in a previous study utilizing pooled sera from egg allergic patients, 5 IgE- and 7 IgG-antibody

binding sites were identified along the 186 amino acid residues comprising ovomucoid (Cooke and Sampson *J. Immunol.* 1997 159, 2026-2032). Evaluation of reduced and alkylated, i.e. "linearized," ovomucoid suggested that not all patients had anti-ovomucoid antibodies that recognized linear epitopes, and that some had antibodies predominantly conformational epitopes.

In the following example, overlapping, linear decapeptides and linearized (reduced and alkylated) whole ovomucoid were utilized to compare individual patient's IgE antibody recognition of linear ovomucoid epitopes. Sera were selected from 17 egg allergic children with relatively high levels of egg-specific IgE antibodies (greater than or equal to 35 kUA/L) for screening ovomucoid epitopes. When IgE binding to the synthesized decapeptides were compared, it appeared that there were three different patterns of antibody binding. As depicted in Figure 3a - 3c, one patient group's IgE antibodies recognized most of the ovomucoid allergenic epitopes previously identified (Cooke and Sampson 1997), one group's IgE recognized allergenic epitopes primarily in the first ovomucoid domain, and the third group had virtually no IgE binding to any of the synthesized decapeptides. In the egg-allergic patients studied, three patterns of ovomucoid-specific IgE binding were seen to the synthesized decapeptides. As reflected in the median cumulative SPOTs IgE *Gal d* 1 OD scores, one group of patients (Group 1; Figure 3a) possessed IgE antibodies to epitopes in all three ovomucoid domains, one group had ovomucoid-specific IgE antibodies primarily to epitopes in the first ovomucoid domain (Group 2; Figure 3b), and one group had negligible IgE antibodies to any synthetic decapeptides (Group 3; Figure 3c).

Since the quantities of egg-specific IgE antibodies were similar in the three groups, this suggested that the third group of patients possessed ovomucoid-specific IgE antibodies that recognized primarily conformational epitopes. This supposition was supported by findings comparing the binding of patients' ovomucoid-specific IgE to "native" and "linearized" (reduced and alkylated) ovomucoid (Figure 5a). While ovomucoid-specific IgE antibody

binding to native ovomucoid was similar in the 3 patient groups, only about 22% of the third groups' ovomucoid-specific IgE bound linearized ovomucoid compared to the native form whereas greater than 50% of the first groups' ovomucoid-specific IgE bound the linearized form of ovomucoid.

These studies have led to the development of a method and assay kit for the determination of the likelihood any particular individual will "outgrow" an allergy, especially a food allergy.

Assay for Determining the Likelihood of Outgrowing an Allergy

Method

The method is based on the discovery that children are more likely to become tolerant to, or "outgrow" allergies to conformational epitopes as compared to linear epitopes. Therefore, the test will typically be performed using blood or serum samples, most preferably from children, although individuals of any age can be tested. These individuals are first identified by screening for allergies using standard tests, for example, by prick skin test or injection of one or more antigens at different titers to determine if the individual is allergic to the antigen and the extent to which the individual is allergic. Antibodies are typically obtained by drawing a sample of the patient's blood, then removing the red cells and testing the remaining serum or plasma. The samples can be screened directly for reactivity of the IgE with defined epitopes presented by the antigen (Cooke and Sampson 1997) or the IgE antibodies separated out from the other antibodies using methods known to those skilled in the art and screened for reactivity. Optionally, the sample can also be screened for IgG antibodies reactive with the epitopes.

Although all 17 egg-allergic patients in the study described in the example developed their egg hypersensitivity in the first two years of life, the first patient group was older and had more pronounced allergic reactions following the ingestion of egg than the third patient group. The first patient group's extensive ovomucoid-specific IgE antibody binding to numerous linear allergenic epitopes is similar to that seen in peanut-allergic patients to *Ara h* 1 and *Ara h* 2, major peanut allergens (Stanley, et al.1997.*Arch.*

Biochem. & Biophysic. 342, 244-253). Patients with peanut allergy tend to have "protracted" (life-long) reactivity to peanut (Bock and Atkins 1989), suggesting the possibility that "protracted" food hypersensitivity is associated with the development of significant quantities of IgE antibodies to linear epitopes. Of note, a 32 year old egg allergic individual, not part of the original 17 who were tested, who has experienced repeated anaphylactic reactions to egg has ovomucoid-specific IgE antibodies with extensive binding to the linear decapeptides, as seen in the first group of patients in this study.

The example supports the association between IgE binding to epitope structure, i.e. linear versus conformational, and the development of "protracted" food hypersensitivity. Infants have been shown to have increased levels of food proteins in the circulation following meals, presumed to be secondary to maturational delay in the development of digestive processes, e.g. stomach acidity, proteolytic enzyme activity, mucin composition, etc., and increased antigen uptake (Hyman, et al. 1985. *J Pediatr* 106:467-471; Lebenthal, E. and P. C. Lee. 1980. *Pediatrics* 66:556-560; Shub,et al. 1983. *Biochem J* 215:405-411; Bresson, et al. 1984. *Pediatr Res* 18:984-987). The "leaky" infant gut would allow significant quantities of conformationally intact food proteins to gain access to local B cells that upon activation generate ovomucoid-specific IgE antibodies in genetically predisposed hosts. With maturation of the gastrointestinal tract, less conformationally intact protein would be accessible to activate gut-associated lymphoid tissue and IgE-bearing tissue mast cells, resulting in loss of clinical reactivity and eventual loss of allergen-specific IgE antibody synthesis. Complete dietary exclusion of egg protein would further promote loss of clinical reactivity, whereas continued exposure to minute amounts of egg protein could result in the development of IgE antibodies to linear ovomucoid epitopes and protracted reactivity. In the mature gut, minute quantities of immunologically intact proteins (probably linear epitopes) penetrate the gastrointestinal barrier (Host 1994; Brunner, M and Walzer M. 1928. *Arch Intern Med* 42:173-179; Wilson SJ and Walzer M. 1935. *Am J*

Dis Child 50:49-54; Husby, et al.1985. *Scand J Immunol* 22:83-92). Conformationally intact proteins are probably excluded. This is consistent with the observation that the likelihood of losing clinical reactivity is associated with the age of the patient at the time of diagnosis, the degree of avoidance of the responsible allergen, and the allergen in question (peanut, tree nut and seafood allergies are rarely "outgrown"). Younger children produce conformational IgE. The younger the patient at the time food sensitivity is diagnosed and/or the more stringent the allergen avoidance, the more likely the patient will "outgrow" his/her food allergy (Bock 1982; Sampson and Scanlon 1989; Pastorello, et al 1989. *J Allergy Clin Immunol* 84:475-483).

Allergens

Any antigen can be used for screening as described herein. The most typical antigens will be food allergens, such as egg, tree nut, peanut, and milk. Other common allergens include pollens, mold, and dust mites, as well as insects, domestic animal (dog, cat, bird), and plants. Allergens are antigens that provide an IgE response.

To test for reactivity with conformational epitopes, the allergens can be utilized as the intact protein, recombinant protein, or proteolytic fragments. The properties of the allergen can be modified by selection of the expression host - for example, bacterial expression systems do not typically glycosylate proteins, yeast and baculovirus/insect systems yield modified glycosylation, and even within eukaryotic expression systems, there can be modifications in glycosylation and phosphorylation, to alter reactivity and further characterize the epitope.

Linear epitopes can be short proteolytic fragments or peptides made by expression of recombinant DNA or synthetically using standard technology. The peptides will typically be from four to forty amino acids in length, more preferably from six to twenty, most preferably eight. These are designed based on the known amino acid sequence, usually available through a public source such as GenBank. The peptides are synthesized in the

preferred embodiment beginning at one through nine amino acid residues, two through ten, and so on to the end of the protein.

The allergen or portion thereof to be tested for binding is preferably immobilized, for example, in a 96 well plate or on a piece of chromatographic paper, and then tested for binding as described in the example. The allergen can be bound to a particle or other known means for solution phase testing, or testing in an ELISA or using a fluorometric technique.

Kits

The method is preferably performed using kits containing the reagents for identifying the IgE antibodies in a patient sample reactive with sufficient linear and conformational epitopes to characterize the patient's prognosis. A typical kit will include a multiwell device having immobilized therein either linear or conformational epitopes to one or more allergens. The kit will also include reagents for detection or separation of IgE from IgG, such as fluorescent labeled immunoglobulin which are specific to IgE, and buffers for washing off unbound materials. The kit can be used to determine the relative amounts of IgE to linear versus conformational antibody by assessing reactivity at different titers to one or more linear epitopes and to one or more conformational epitopes, then determining their relative proportions.

The result of the test is typically a ratio of the proportion of IgE reactive with linear versus conformational epitopes, without reference to a negative or positive control, although it may be desirable to include positive and negative IgE samples reactive with either linear or conformational epitopes to insure the integrity of the test kit reagents and assay conditions.

Methods for Treatment of Allergies, especially Food Allergies

Those individuals having primarily IgE reactive with conformational epitopes are more likely to outgrow the allergy than those characterized principally by reactivity with linear epitopes. This is further demonstrated by the examples. In infants predisposed to atopy, the development of IgE antibodies to conformational versus linear epitopes may in part reflect

maturational delay and/or molecular differences in antigen-processing by the gastrointestinal tract, immaturity of the gut, and allergen exposure. Studies on the prevention of allergy in infants at "high risk" for developing atopy have shown that complete avoidance of cow milk (a major food allergen) for at least the first year of life results in less milk allergy compared to infants placed on no dietary restriction (Zeiger,et al. 1989. *J Allergy Clin Immunol* 84:72-89; Halken, et al. 1992. *Allergy* 47:545-553.).

Based on the above information, one is able to develop generalized screening methods and formulations for screening, to aid in the decision whether or not a patient should undergo an immunotherapeutic modality to induce tolerance in allergic patients. Immunotherapeutic modalities that may be prescribed based on the results of the screening include complete avoidance of the allergen, for example, the food that contains the epitopes reactive with the patient IgE, or desensitization therapy.

Method for Assessing Prognosis in Inflammatory Disorders

IgG antibodies to food proteins can be detected in virtually all individuals exposed to food antigens (Johansson,et al. *Ann Allergy* 53:665-672; Savilhati, et al.1987. *Acta Paediatr Scand* 76:1-6) although levels of IgG food-specific antibodies tend to decrease with age (Kletter, et al. 1971. *Int Arch Allergy Appl Immunol* 40:656-666). Patients with food allergies or inflammatory bowel disorders (e.g. celiac disease, inflammatory bowel disease, etc.) tend to have markedly elevated levels of food-specific IgG (May,et al. 1977. *Clin Allergy* 7:583-595). The same would be expected in the case of IgA antibodies, which are predominantly found in the lining of the gastrointestinal tract..

The example demonstrates that patients with protracted egg allergy possess large quantities of IgE antibodies that bind linear ovomucoid epitopes whereas younger patients possess primarily IgE antibodies that bind conformational epitopes. In addition, egg allergic patients develop significant quantities of ovomucoid-specific IgG antibodies to linear and conformational epitopes whereas non-egg allergic individuals develop ovomucoid-specific IgG almost exclusively to conformational epitopes.

As noted above, elevated levels of food-specific IgG antibodies also are seen in disorders marked by inflammation of the gastrointestinal tract, e.g. Crohn's disease, ulcerative colitis, celiac disease, etc. (Sampson, H.A.: 1995 11(6), 548-553). It is believed that the elevated food-specific antibodies are secondary to increased gut permeability in these disorders and are not pathogenic. In uncomplicated inflammatory bowel disorders, it is likely that these food-specific IgG antibodies are directed at conformational epitopes. However, in progressive, refractory bowel disease, food-specific IgG antibodies are believed to be directed at linear epitopes, indicating an abnormal immune response and unfavorable prognosis.

As shown by the example, when ovomucoid-specific IgG antibody binding to linear decapeptides were evaluated, significant differences were seen between egg-allergic patient groups and controls. The first patient group, which had the greatest amount of ovomucoid-specific IgE to the linear decapeptides, had significantly less ovomucoid-specific IgG antibody binding to the ovomucoid decapeptides than the second and third patient groups (Figure 4a - 4c). As reflected in the median cumulative SPOTs IgG *Gal d* 1 OD scores, egg-allergic patients (Figures 4a - 4c) had extensive IgG binding to epitopes in all three ovomucoid domains and significantly more ovomucoid-specific IgG antibodies to the SPOTs decapeptides than non-egg-allergic controls: atopic dermatitis patients without egg allergy (Figure 4d) and non-allergic normal controls (Figure 4e). The second (Figure 4b) and third (Figure 4c) groups of egg allergic patients had significantly more IgG antibody binding to the synthesized peptides than the first group (Figure 4a). However, there was no significant difference in the percentage of ovomucoid-specific IgG binding to "linearized" ovomucoid compared to the native form (Figure 5b). Control groups consisting of atopic dermatitis patients who were not allergic to egg and non-allergic normal controls had significant IgG antibodies to native ovomucoid but virtually no ovomucoid-specific IgG antibodies to the linear decapeptides (Figure 4d - 4e). These results suggest a qualitative difference at the level of antigen processing

between food allergic and non-allergic individuals in their immune response to ingested allergens.

It is therefore possible to screen for those individuals having inflammatory disorders which are likely to be characterized by progressive, refractory bowel disease, as compared to uncomplicated inflammatory bowel disorders. The methods and reagents are similar to those for determining the likelihood an individual will outgrow an allergy based on the relative proportions of IgE immunoreactive with linear versus conformational epitopes, but examining the immunoreactivity of IgG to linear versus conformation epitopes.

The present invention will be further understood by reference to the following non-limiting example.

Example: Screening of patient samples to characterize the immunoreactivity of anti-egg IgE and IgG.

METHODS AND MATERIALS

Abbreviations:

PBS - phosphate buffered saline

SDS-PAGE = sodium dodecylsulfate polyacrylamide gel electrophoresis

Patient Population

Seventeen children (median age: 4 yrs., range: 1 - 15 yrs.; 10 males, 7 females) presenting for evaluation of atopic dermatitis were diagnosed with egg hypersensitivity by double-blind placebo-controlled egg challenge, as described by Sampson, H.A. and C.C. McCaskill. 1985. *J Pediatr* 107:669-675; and Sampson, H.A. 1992. *Acta Derm Veneorol (Stockh)* Suppl. 176:34-37. Blood was obtained by venous puncture, and the sera separated and stored frozen at -20°C until used in the study. Serum egg-specific IgE concentrations were determined utilizing the CAP-RAST FEIA™ system (Pharmacia Diagnostics; Uppsala, Sweden).

Preparation of reduced and alkylated ovomucoid

Ovomucoid was reduced and alkylated by dissolving whole ovomucoid in PBS at a concentration of 50 mg/ml, as described by Cooke and Sampson. *J. Immunol.* 1997.

SDS-Polyacrylamide Gel Electrophoresis

Proteins were separated by SDS-PAGE as previously published (Bernhisel-Broadbent, et al. 1989. *J Allergy Clin Immunol* 84:701-709). Protein sample concentrations were optimized to give equivalent signal when stained by amido black and analyzed by laser densitometry. The resolved proteins were subsequently transferred to nitrocellulose and then stained with amido black to look for total protein transfer, or blocked with PBS-Tween with 0.5% porcine gelatin for probing with patient sera.

Probing Immunoblots with Patient Sera

Patient sera were diluted 1:10 in PBS-Tween plus gelatin, incubated with immunoblots for 2 hours with gentle agitation at room temperature, and developed for IgE and IgG antibodies as previously described (Cooke and Sampson 1997). Immunoblots were developed with BCIP/NBT (SigmaFAST; Sigma Chemical, St. Louis, MO) and scanned with a laser densitometer (Ultrascan SL; Pharmacia Biotech, Piscataway, NJ) to determine the amount of ovomucoid-specific antibody bound.

Screening for IgE and IgG Epitopes

In this study, the SPOTs^{TM} membrane (Genosys Biosystems; The Woodlands, TX), a derivatised cellulose membrane was used to generate decapeptides in an 8 x 12 matrix of small circular spots. Using this method, 89 decapeptides representing the entire sequence of *Gal d* 1 were generated; peptides overlapped by 8 amino acids, e.g. peptide #1 = *Gal d* 1 amino acids 1 - 10, peptide #2 = *Gal d* 1 amino acids 3 - 12, peptide #3 = *Gal d* 1 amino acids 5 - 14, etc.

Prior to screening the overlapping *Gal d* 1 peptides with patient sera, the SPOTs membrane was blocked with PBS (pH 7.2) containing 0.01% Tween 20, 0.5% porcine gelatin, and 1% human serum (from a donor with no detectable IgE to egg proteins). Individual patient sera were diluted 1:12 in PBS with 0.01% Tween 20 and 0.5% porcine gelatin (PBS-Tween+gel), incubated on a rocking platform at room temperature for 2 hours, and developed for IgE antibodies as previously described (Cooke and Sampson 1997). For detecting patient IgG antibodies, patient sera were diluted 1:10 in

PBS-Tween+gel. Incubation times and washes were the same as for IgE antibody. The detecting antibody used was rabbit anti-human IgG-HRP conjugate (Dako Corp, Santa Barbara, CA). The membrane was developed with the ECL chemiluminescent HRP detection kit (Amersham, Arlington Heights, IL).

After developing the x-ray film, the optical density (OD) of each individual peptide spot was measured using a reflection densitometer (The Answer II MacBeth, Newburgh, NY). The OD of each peptide spot was recorded as the difference between the actual peptide spot OD and the background film OD. Each of the 89 decapeptides was assigned a "cumulative SPOTs" IgE and IgG *Gal d* 1 OD score, which represented the sum of the ODs for each of the 89 *Gal d* 1 SPOT peptides for the 17 patients studied. Each patient received a "cumulative patient" IgE and IgG *Gal d* 1 OD score, which represented the sum of the ODs for all 89 *Gal d* 1 SPOT peptides for that patient.

The SPOTs membrane could be regenerated and re-probed 8 to 10 times. After rinsing the membrane thoroughly in deionized, distilled water, it was washed 3 times in 8 M urea containing 35 Mm SDS and 0.1% BME for 10 minutes each time to strip IgE or 30 minutes to strip IgG. The membrane was then washed three times (10 minute washes) in 50% ethanol and 10% acetic acid, twice (10 minute washes) in methanol, and then re-blocked for re-probing. Incubation of the membrane with the secondary antibody alone (anti-human IgE or IgG) following the stripping procedure in the absence of patient serum revealed no non-specific binding, indicating that the stripping procedure had successfully regenerated the SPOTs membrane.

Statistical Analysis

All analyses of data were performed with non-parametric tests, the paired, two-sample sign test and the Mann Whitney test.

RESULTS

Sera from 17 children with egg allergy confirmed by double-blind placebo-controlled food challenges were utilized in the study. All had markedly elevated serum egg-specific IgE; median - 83 Kua/L; range - 35 to

greater than 100 kUA/L. Individual patients' sera were used to probe the SPOTs membrane for IgE and IgG peptide-specific antibodies. Figure 1 depicts the cumulative SPOTs IgE *Gal d* 1 O.D. scores for each of 89 synthetic peptides. Peptides #1, #5, #6, #24, #25, and #57 were bound by IgE antibodies from greater than 50% of the patients, indicating that these peptides represent "major allergenic epitopes." These major allergenic epitopes, represent *Gal* d 1 amino acids 1-10 (peptide 1, AEVDCSRFPN), 9-20 (peptides 5 and 6, PNATDKEGKDVL), 47-58 (peptides 24 and 25, SIEFGTNISKEH), and 113-122 (peptide 57, VEQGASVDKR). Other synthetic peptides with significant IgE *Gal d* 1 SPOTs OD scores included peptides 2 (amino acids 3-12, VDCSRFPNAT), 4 (amino acids 7-16, RFPNATDKEG), 21 (amino acids 41-50, CLLCAYSIEF), 38 and 39 (amino acids 75-86, NTTSEDGKVMVL), 53 (amino acids 105-114, ECLLCAHKVE) and 89 (amino acids 177-186, TLTLSHFGKC). Most of these peptides were bound by IgE antibodies from 6 or more patients. Figure 2 depicts the cumulative IgG *Gal d* 1 SPOTs O.D. scores for each of the 89 synthetic decapeptides. There was more extensive binding of IgG antibodies to the *Gal d* 1 synthetic peptides compared to the IgE binding.

When IgE antibody binding to the SPOTs membranes; decapeptides for each patient were compared, three different patterns of peptide binding were seen: **Group 1** - IgE antibodies bound epitopes in two or more *Gal d* 1 domains, **Group 2** - IgE antibodies specific for peptides primarily in the first *Gal d* 1 domain, and **Group 3** - negligible IgE binding to any of the decapeptides on the SPOTs membrane. Although there were no significant differences ($p>0.4$) in the serum egg-specific IgE concentrations among the 3 patient groups (Group 1 (n=5) - 80 kUA/L, Group 2 (n=5) - 92 kUA/L, and Group 3 (n=7) - 73 kUA/L), the median cumulative SPOTs IgE *Gal d* 1 OD scores for the three patient groups differed significantly. Group 1 patients had significantly more IgE binding (median cumulative OD=27.9) to the synthesized *Gal d* 1 decapeptides than either Group 2 (median cumulative OD=7.0; $p<0.05$) or Group 3 (median cumulative OD=2.7; $p<0.01$), and Group 2 had significantly more IgE binding to *Gal d* 1 peptides than Group 3

($p<0.05$). The median IgE binding to individual decapeptides for each patient group is depicted in Figure 3. Interestingly, patients in Groups 1 and 2 tended to be older with longer-standing egg allergy compared to patients in Group 3; median age 10 and 6 years, respectively, with all patients diagnosed within the first 2 years of life.

Figure 4a - 4e depict the median IgG binding to individual decapeptides for each of the 3 patient groups and 2 sets of controls. Significant differences in median cumulative patient IgG *Gal d* 1 OD scores were seen among the three patient groups and controls: Group 1 - 52.4, Group 2 - 70.6, Group 3 - 69.8, non-food allergic atopic dermatitis controls ($n=5$) - 9.6, non-allergic controls ($n=5$) - 11.6. Group 1 patients had significantly less IgG antibody binding to *Gal d* 1 decapeptides than Groups 2 and 3 ($p<0.01$), whereas there was no significant difference between Groups 2 and 3 ($p=0.4$). The three egg allergic patient groups had significantly more IgG binding to the ovomucoid decapeptides than the two non-egg allergic control groups ($p<0.01$). The non-egg allergic atopic dermatitis patient controls and non-atopic controls showed similar ($p=0.4$), minimal IgG antibody binding to the 89 SPOTs decapeptides.

The lack of IgE binding to the synthesized peptides by Group 3 egg-allergic patients suggested that the majority of their ovomucoid-specific IgE antibodies recognized conformational epitopes. To examine this, IgE antibody binding to native and reduced and alkylated (linearized) ovomucoid was compared in the three patient groups. Figures 5a-b depict the ratios of IgE antibody binding (OD) to reduced and alkylated ovomucoid compared to IgE antibody binding to native ovomucoid. The ratio of ovomucoid-specific IgE and IgG antibodies to native and "linearized" (reduced and alkylated) ovomucoid were compared for each egg allergic patient group. Although IgE antibody concentrations to native ovomucoid were comparable for all groups, Group 1 patients, who were older with longstanding egg allergy, had significantly more IgE antibodies to linearized ovomucoid than Group 3 patients, who were younger (Figure 5a). (Figure 5a - medians: 52% vs. 22% for Groups 1 and 3, respectively, $p<0.05$). No significant differences in the

ratio of IgG antibodies to linearized-native ovomucoid were seen among the egg-allergic patient groups (Figure 5b).

I claim:

1. A method of classifying food allergic patients with respect to the likelihood that their food allergy will be outgrown, the method comprising the steps of

providing a sample of antibodies from a food allergic patient;

contacting the antibody sample with a collection of linear epitopes of a food allergen;

contacting the antibody sample with at least one conformational epitope of the food allergen; and

classifying the patient as more likely to outgrow allergy to the food allergen if the antibody sample shows relatively more binding to the at least one conformational epitope as compared with the linear epitopes

2. A method of classifying food allergic patients with respect to the likelihood that their food allergy will be outgrown, the method comprising the steps of

providing a sample of antibodies from a food allergic patient;

contacting the antibody sample with a collection of linear epitopes of a food allergen;

contacting the antibody sample with at least one conformational epitope of the food allergen; and

classifying the patient as less likely to outgrow allergy to the food allergen if the antibody sample shows significant binding to the linear epitopes.

3. The method of claim 1 or 2 wherein the epitopes in the library are immobilized for screening.

4. The method of claim 1 or 2 comprising first screening to determine which antigens the individual is allergic to.

5. The method of claim 1 or 2 for determining the likelihood of an individual outgrowing an allergy, comprising

providing a sample comprising IgE antibodies from an individual with an allergy,

screening the sample for reactivity of the IgE antibodies with one or more linear epitopes and one or more conformational epitopes, and determining whether the IgE is primarily reactive with epitopes in the library which are

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conformational epitopes selected from the group consisting of native protein and proteolytic fragments of native protein, wherein the individual is predicted to outgrow the allergy to the epitopes reactive with the IgE, or the IgE is primarily reactive with epitopes in the library which are linear epitopes selected from the group consisting of reduced and alkylated protein and synthetic linear peptides, wherein the individual is predicted to not outgrow the allergy to the epitopes reactive with the IgE.

6. The method of claim 5 wherein the epitopes are derived from antigens selected from the group consisting of food, pollens, dust, molds, insect, animal, and plant proteins.

7. The method of claim 6 wherein the antigens are derived from foods.

8. The method of claim 7 wherein the epitopes are derived from antigens selected from the group consisting of peanut, egg, tree nuts, milk, fish, and shell fish.

9. A method for determining the likelihood that an inflammatory disorder is progressive and refractory, comprising the steps of

providing a sample comprising IgG or IgA antibodies from an individual with an inflammatory disorder;

screening the sample for reactivity of the IgG or IgA antibodies with one or more linear epitopes and one or more conformational epitopes; and

determining whether the IgG or IgA is primarily reactive with the conformational epitopes, wherein the inflammatory disorder is probably not progressive and refractory, or the IgG or IgA is primarily reactive with the linear epitopes, wherein the inflammatory disorder is probably progressive and refractory.

10. The method of claim 9 wherein the inflammatory disorder is of the gastrointestinal tract.

11. The method of claim 10 wherein the inflammatory disorder is selected from the group consisting of Crohn's disease, ulcerative colitis, and celiac disease.

12. The method of claim 11 wherein the antibodies are IgA antibodies.

13. A kit when used in the method of claim 1 or 2 for classifying food allergic patients with respect to the likelihood that their food allergy will be outgrown, the kit comprising:

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a collection of linear epitopes from at least one food allergen; and

at least one conformational epitope from the at least one food allergen.

14. The kit of claim 13 wherein the epitopes are immobilized in a multi-well device for screening.

15. The kit of claims 13 or 14 further comprising as part of the kit reagents for the detection of IgE, IgA or IgG antibodies.

16. The kit of claim 15 wherein the kit is for the evaluation of patients with allergies and the reagents detect IgE.

17. The kit of claim 15 wherein the kit is for the evaluation of patients with inflammatory disorders and the reagents detect IgG.

18. The kit of claim 15 wherein the kit is for the evaluation of patients with inflammatory bowel disease and the reagents detect IgA.

19. The kit of claim 13 wherein the food allergen is a food protein.

20. The kit of claim 13 wherein the food is selected from the group consisting of peanut, egg, tree nuts, milk fish and shellfish.

21. The method of claim 1 or 2, wherein the linear epitopes are selected from the group consisting of natural purified antigens, recombinant antigens, synthetic antigens and antigen fragments.

22. The method of claim 1 or 2, wherein the linear epitopes are selected from the group consisting of peptides that are four and 40 amino acids in length based on amino acid sequence in the antigen and reduced and alkylated antigens and antigen fragments.

23. The method of claim 1 or 2, wherein the conformational epitopes are selected from the group consisting of natural purified antigens, recombinant antigens, synthetic antigens and antigen fragments.

24. The kit of claim 13, wherein the linear epitopes are selected from the group consisting of natural purified antigens, recombinant antigens, synthetic antigens and antigen fragments.

25. The kit of claim 13, wherein the linear epitopes are selected from the group consisting of peptides that are four and 40 amino acids in length based on amino acid sequence in the antigen and reduced and alkylated antigens and antigen fragments.

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26. The kit of claim 13, wherein the conformational epitopes are selected from the group consisting of natural purified antigens, recombinant antigens, synthetic antigens and antigen fragments.

27. A method of classifying food allergic patients substantially as herein described.

28. A method of determining the likelihood that an inflammatory disorder is progressive and refractory substantially as herein described.

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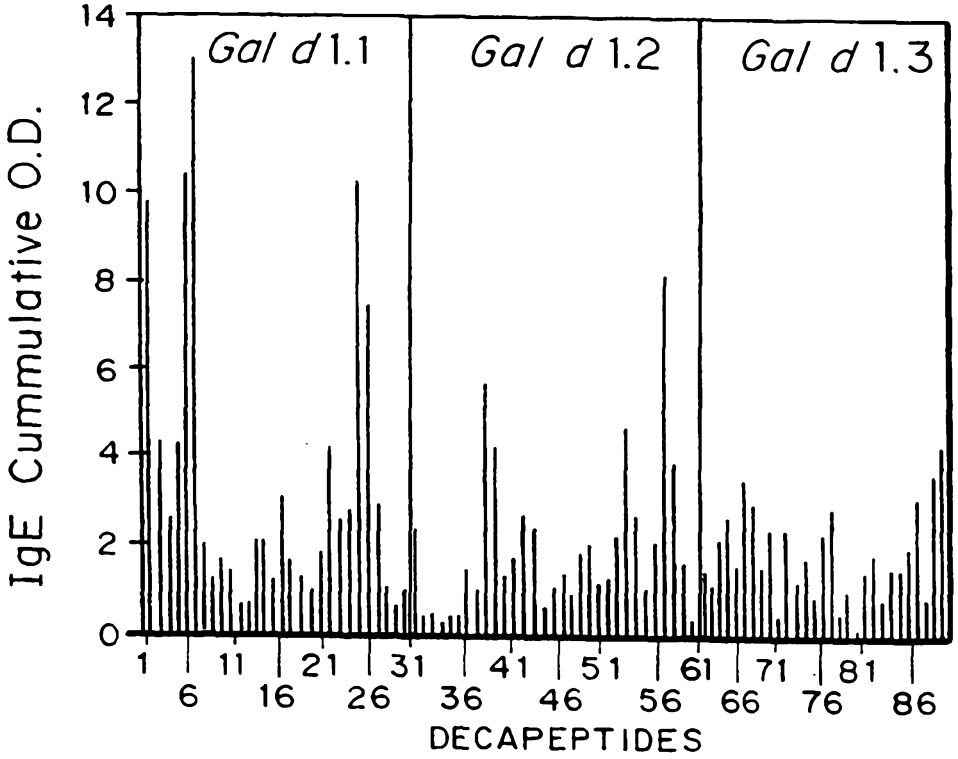
Gal d 1.1
Gal d 1.2
Gal d 1.3
IgE Cummulative O.D.
0
2
4
6
8
10
12
14
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
DECAPEPTIDES

FIG. 1

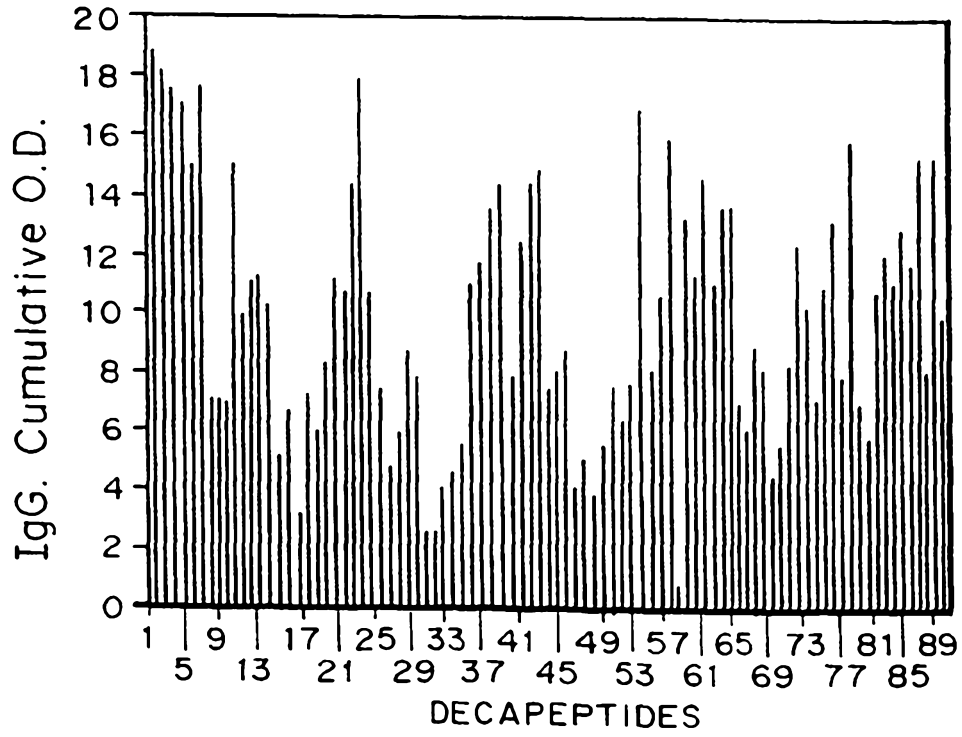
IgG. Cumulative O.D.
0
2
4
6
8
10
12
14
16
18
20
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
DECAPEPTIDES

FIG. 2

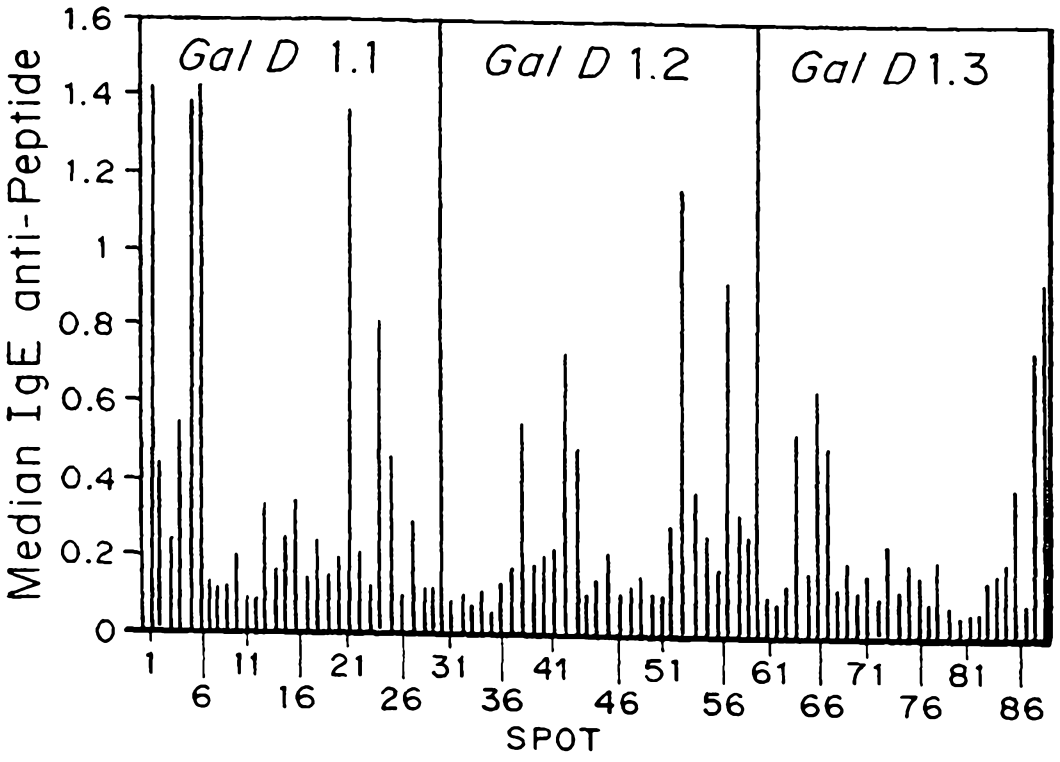
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgE anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86
SPOT

FIG. 3A

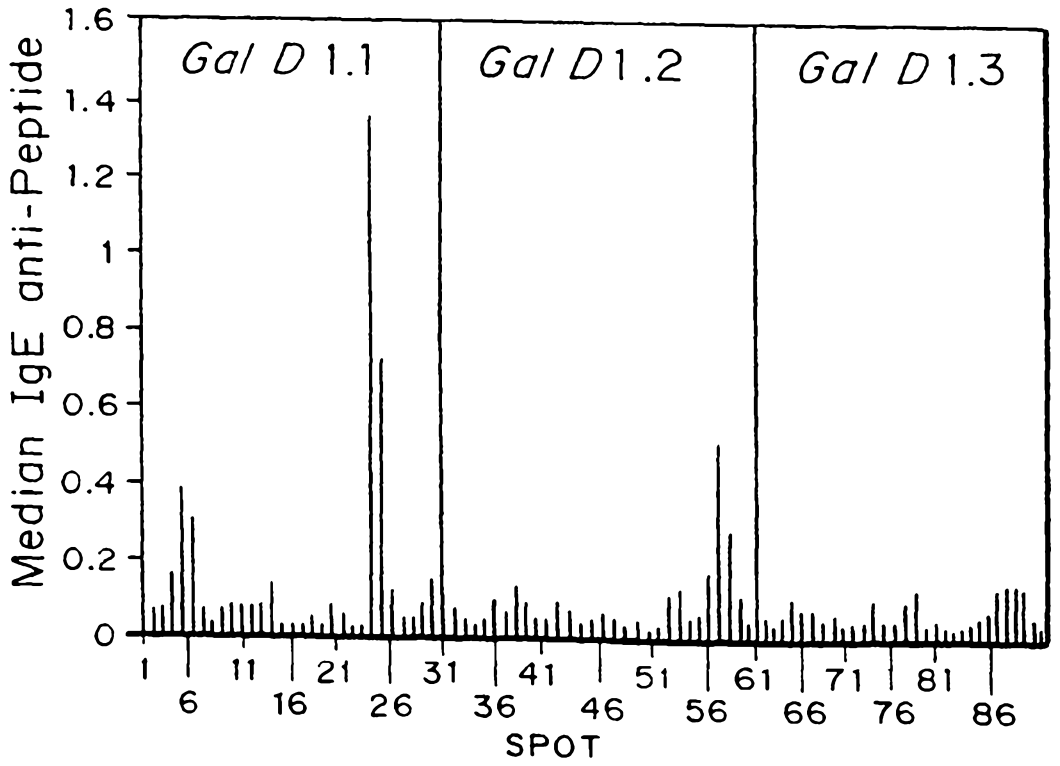
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgE anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86
SPOT

FIG. 3B

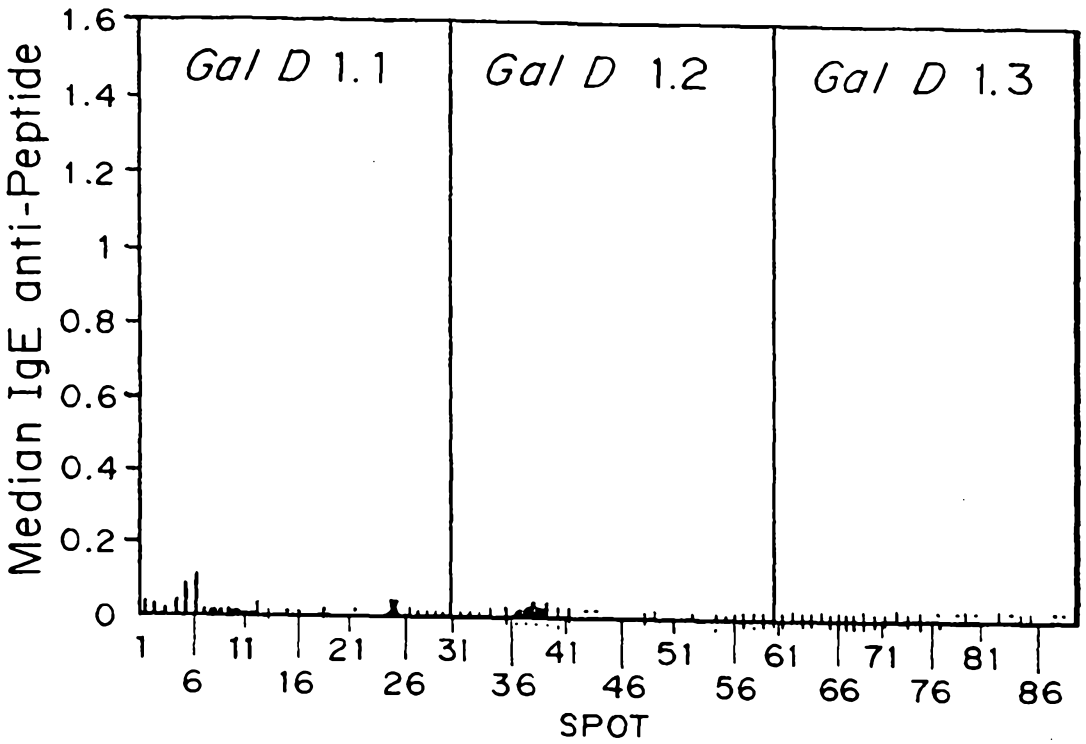
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgE anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86
SPOT

FIG. 3C

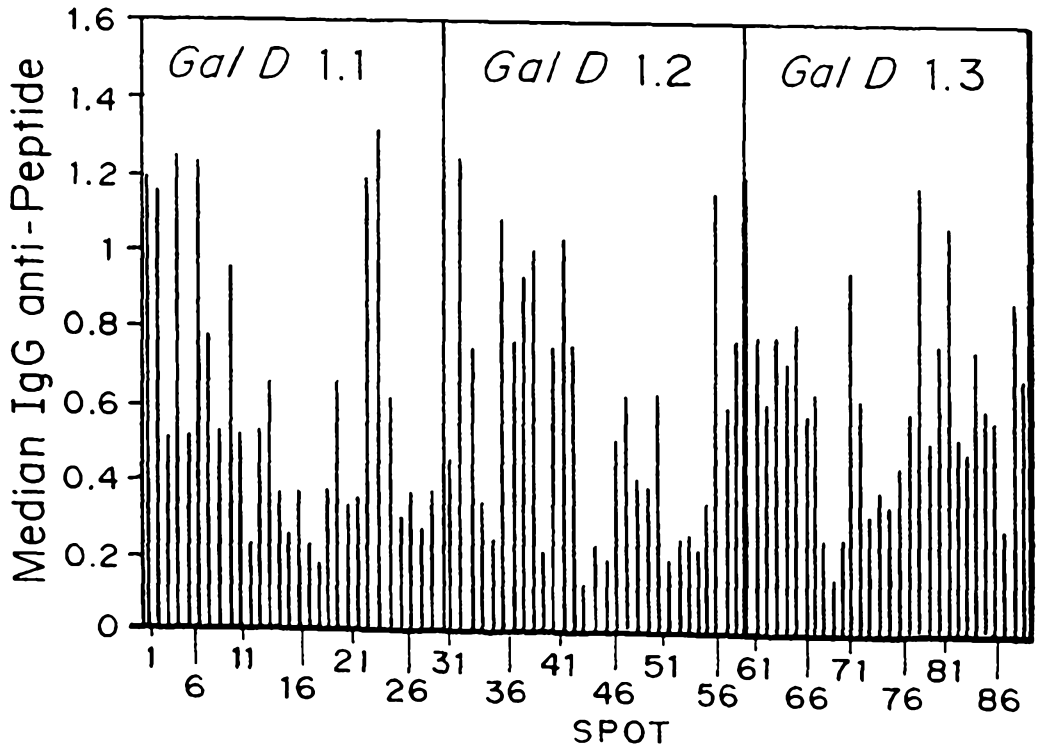
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgG anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86
SPOT

FIG. 4A

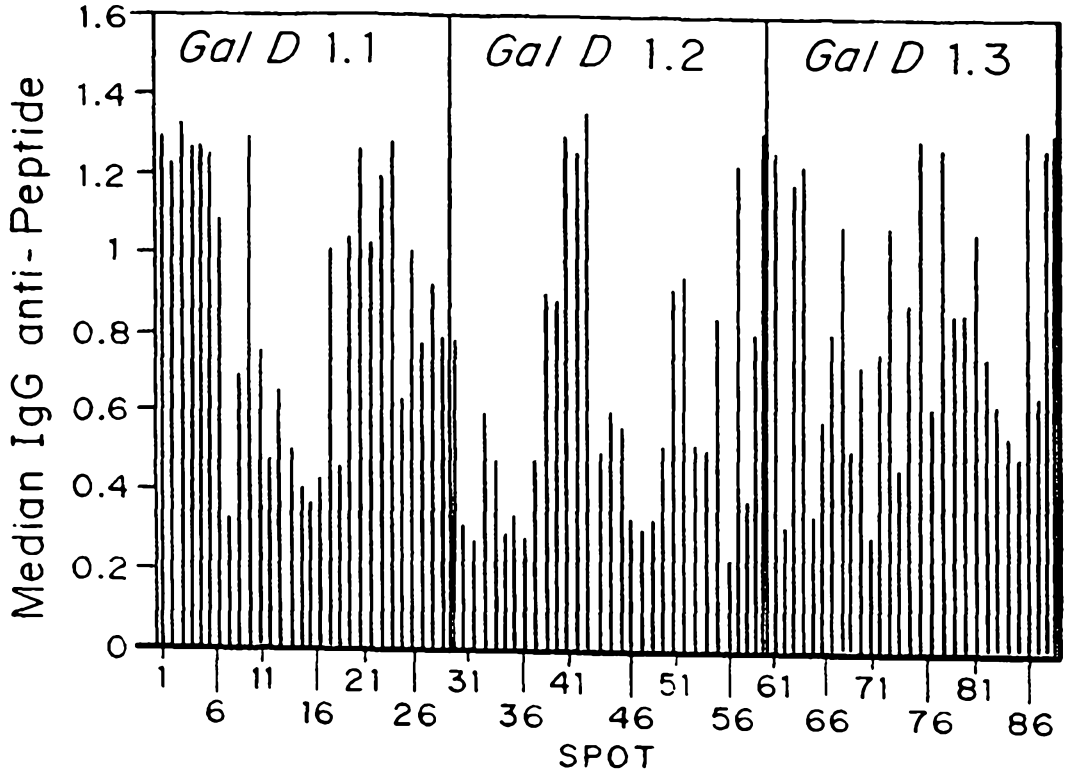
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgG anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
SPOT

FIG. 4B

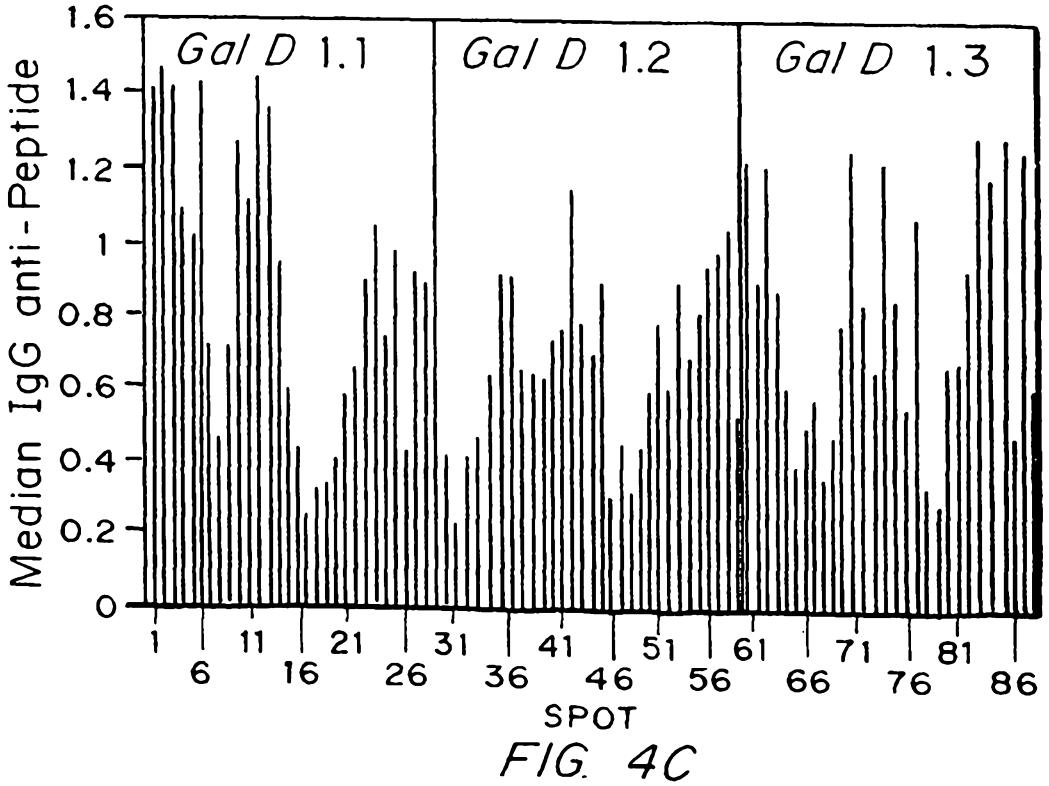
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgG anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
SPOT

FIG. 4C

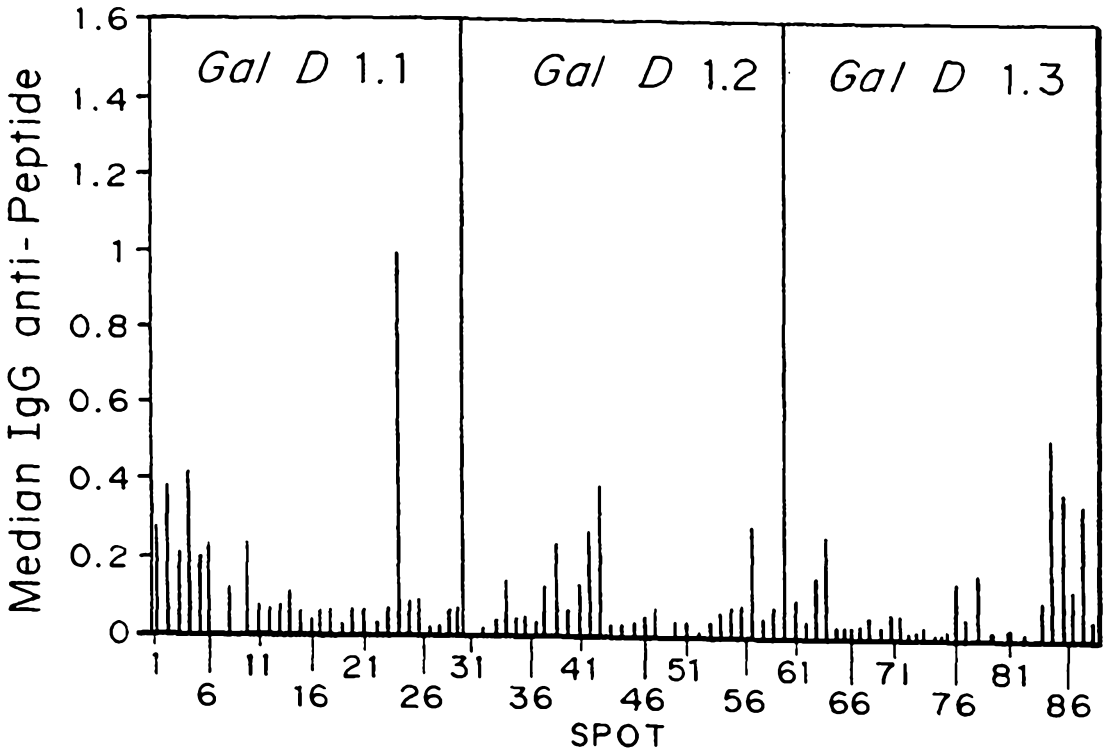
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgG anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
SPOT

FIG. 4D

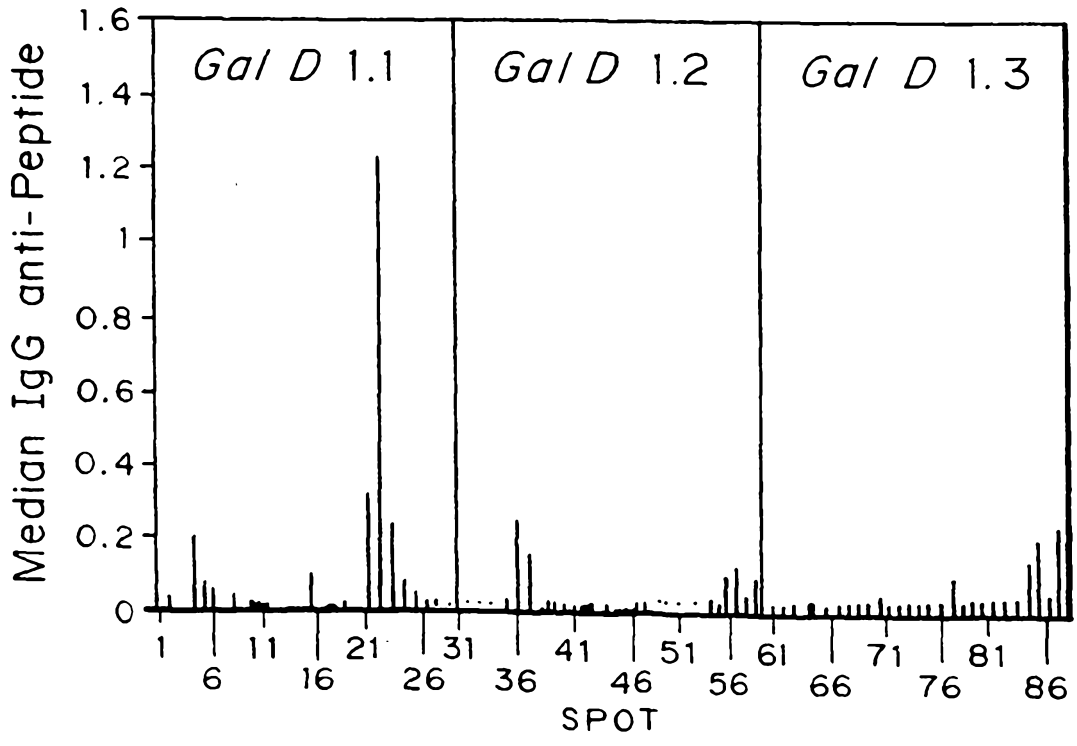
Gal D 1.1
Gal D 1.2
Gal D 1.3
Median IgG anti-Peptide
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
SPOT

FIG. 4E

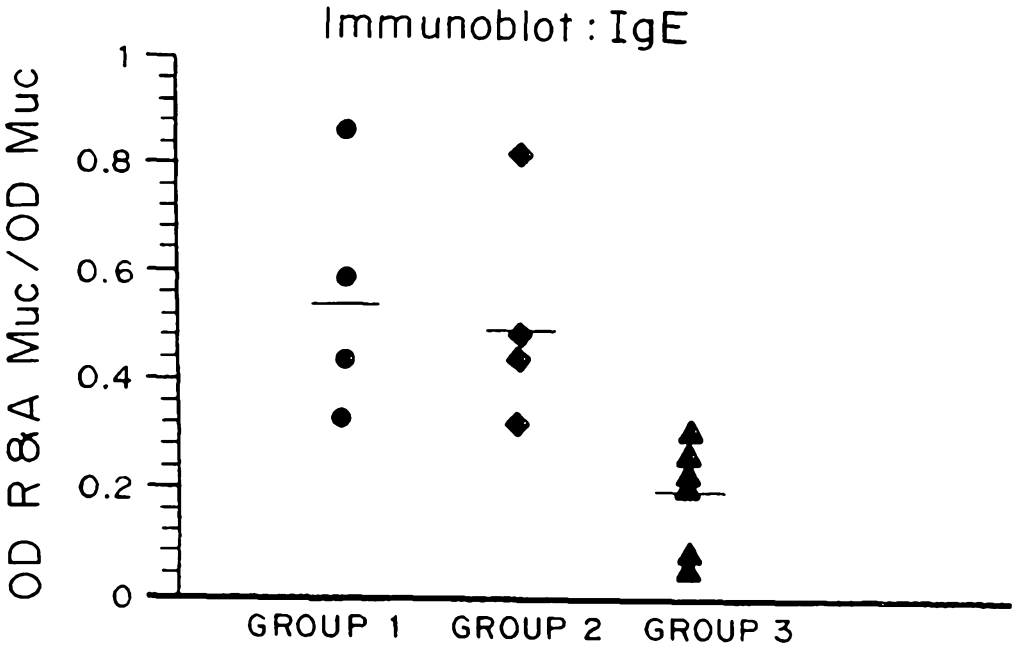
Immunoblot : IgE
OD R&A Muc/OD Muc
1
0.8
0.6
0.4
0.2
0
GROUP 1
GROUP 2
GROUP 3

FIG. 5A

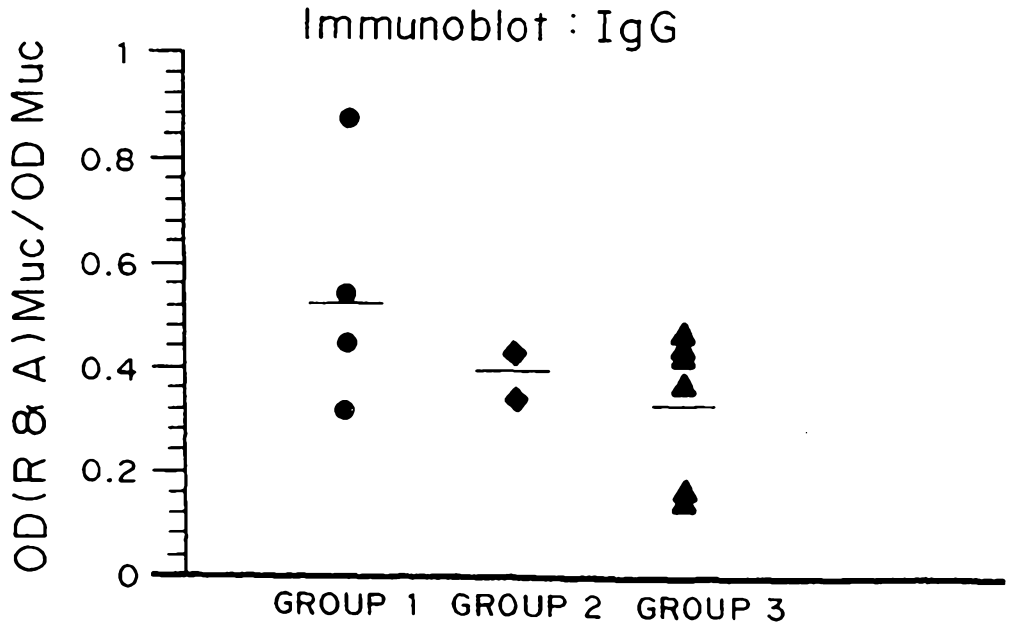
Immunoblot : IgG
OD(R & A)Muc/OD Muc
1
0.8
0.6
0.4
0.2
0
GROUP 1
GROUP 2
GROUP 3

FIG. 5B