Available online at http://jddtonline.info

REVIEW ARTICLE

FOOD ALLERGENICITY AND ASSOCIATED RISK FACTORS: AN OVERVIEW

*Kumawat MK, Jha AK

Anand College of Pharmacy, Keetham, Agra, INDIA-282007
*Corresponding Author's Email: phmukesh@gmail.com

Received 20 Sep 2011; Revised 27 Sep 2011; Accepted 10 Oct 2011, Available online 26 Oct 2011

ABSTRACT

The immune system protects our body against pathogens and other foreign substances by producing a kind of glycoprotein known as immunoglobulin or antibodies from plasma cells or B-cells. Surveys show that about one-third of all adults believe they have food allergies. About 4-8% percent of young children are diagnosed with food allergies, most of which are evident in the first years of life and are often outgrown. A food allergy is any adverse reaction to an otherwise harmless food or food component that involves the body's immune system. In others a word, a food allergy is an immune system response to a food that the body mistakenly believes is harmful. Components of a food that trigger the immune system are called food allergens. Cows' milk allergy appears to be among the more prevalent food allergies in infants. Eggs and peanuts are also common allergenic foods for infants, along with soybeans, tree nuts, fish, and wheat. Seafood allergies, especially to crustaceans (shrimp, crab, lobster) are also rather common among adults. The present review provides brief information about food allergy and allergic reactions, their types, symptoms and approaches for reduction.

Keywords: food allergy, adverse reactions, immune system, top allergens.

INTRODUCTION

Allergy is one of the most widespread diseases of the modern world. More than 25% of the population in industrialized countries suffers from allergies.[1] The immune system protects our body against pathogens and other foreign substances by producing a kind of glycoprotein known as immunoglobulin (Ig) or antibodies from plasma cells or B-cells (a type of lymphocyte). Antibodies are mainly of five types, each one having a different function; the type involved in allergy is immunoglobulin E (IgE). Immunoglobulin E (IgE) is overproduced during an allergic response. On the very first exposure to an allergen, an allergic person becomes sensitized by producing allergen specific IgE that binds with IgE receptors on mast cells (in tissues) and basophils (in circulation). Binding of two or more IgE molecules to mast cells (cross linking) is required to activate the mast cells. These activated cells result in the release of certain chemicals, such as histamine, serotonin, proteoglycans, serine protease, leukotriene C4 and heparin, which will further bind with their receptors present in other cells (e.g., histamine receptors of blood vessels) and lead to inflammation, irritation, redness and other allergic symptoms.[2]

Pollen is one of the major causes of allergies. Some of the most common allergy-inducing pollens are from birch, olive, oak, maple, plantago, rye grass, and ragweed. Major pollen allergens constitute expansins, profilins and calcium-binding proteins. Food plants such as cooked potatoes, apples, beans, tomatoes, onions, cabbage, soy, peanuts, and the wheat proteins omega-5 gliadin and glutein can also cause allergies.[3] Latex is also a strong trigger for allergic disease. [4-6] Allergens can be of animal origin. In most edible fish, parvalbumin has been identified as the major allergen. Fish like cod, salmon, pollack, herring, and wolfish contain the most potent allergens, whereas halibut, flounder, tuna and mackerel are the least allergenic. [7] Eight foods or food groups are thought to account for more than 90% of all IgE-mediated food allergies on a worldwide basis. These top eight food allergens are:

- ✓ *Milk*
- ✓ *Shellfish (*crab, lobster, shrimp *and mollusks)*
- ✓ *Eggs*
- ✓ *Wheat*
- ✓ *Fish (*bass, flounder, cod*)*
- ✓ *Peanuts*
- ✓ *Soy*
- ✓ *Tree nuts (*almonds, walnuts, pecans, *walnuts)*

SYMPTOMS OF FOOD ALLERGY

Clinical symptoms of adverse food reactions typically involve the skin, gastrointestinal tract, and respiratory system. These symptoms can occur alone or in combination, with more than one symptom occurring at one time; and in some cases there can be generalized anaphylaxis. IgE-mediated adverse reactions to food or food allergy usually begin within minutes to a few hours after eating the offending food. But in very sensitive people, simply touching or inhaling the food may produce an allergic reaction. Anaphylaxis is a rare but potentially fatal condition in which several different parts of the body experience food allergic reactions at the same time. Symptoms may progress rapidly and may include severe itching, hives, sweating, swelling of the throat, breathing difficulties, lowered blood pressure, unconsciousness and can even lead to death.[8-12]

Table 1: Symptoms of IgE and Non-IgE-mediated Food Allergy[8-12]

IgE-mediated	Non-IgE-mediated
Acute urticaria - localised or generalised.	Atopic eczema.
Acute angio-oedema- commonly mouth, lips, face, around eyes	Gastro-oesophageal reflux.
Oral itching, nausea, vomiting.	Infantile colic.
Colicky abdominal pain.	Stools: loose &/or frequent, blood &/or mucus
Nasal itching, sneezing, rhinorrhoea, allergic conjunctivitis.	Constipation.
Cough, shortness of breath, wheezing and bronchospasm	Perianal redness.
	Pallor and tiredness.
Other signs of anaphylaxis, feeling of impending doom, cardiovascular collapse.	Faltering growth.
	Food aversion or avoidance.

TYPES OF THE ADVERSE FOOD REACTIONS

Food allergy is thought to develop more easily in patients with the atopic syndrome, a very common combination of diseases: allergic rhinitis and conjunctivitis, eczema and asthma.[13]The syndrome has a strong inherited component; a family history of allergic diseases can be indicative of the atopic syndrome.

Conditions caused by food allergies are classified into 2 groups according to the mechanism of the allergic response:

1. IgE-mediated (classic):

- ✓ Type-I immediate hypersensitivity reaction (symptoms described above)
- ✓ Oral allergy syndrome

2. Non-IgE mediated:

- ✓ Food protein-induced Enterocolitis syndrome (FPIES)
- ✓ Food protein proctocolitis/proctitis
- ✓ Food protein-induced enteropathy. An important example is Celiac disease, which is an adverse immune response to the protein gluten.
- ✓ Milk-soy protein intolerance (MSPI) is a non-medical term used to describe a non-IgE mediated allergic response to milk and/or soy protein during infancy and early childhood. Symptoms of MSPI are usually attributable to food protein proctocolitis or FPIES.
- ✓ Heiner syndrome — lung disease due to formation of milk protein/IgG antibody immune complexes (milk precipitins) in the blood stream after it is absorbed from the GI tract. The lung disease commonly causes bleeding into the lungs and results in pulmonary hemosiderosis.

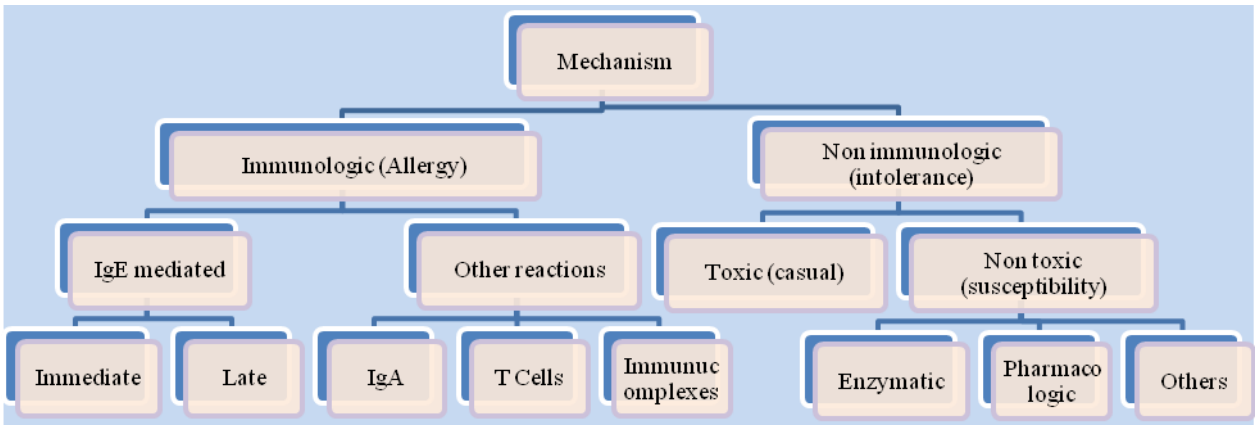

Figure 1: Classification of the adverse food reactions

PREVALENCE OF FOOD HYPERSENSITIVITY

The prevalence of food hypersensitivities is greatest in the first few years of life, affecting about 6% of infants less than 3 years of age[14] and decreasing over the first decade. Virtually all infants who have cow's milk allergy have it in the first year of life, with clinical tolerance developing in about 80% by their fifth birthday.1 About 60% of infants with cow's milk allergy experience IgE-mediated reactions, and about 25% of these infants retain their sensitivity into the second decade of life, with 35% going on to have other food allergies.[15] Table I lists the prevalence of various food allergies in the United States on the basis of the most recent studies. Although it was once thought that peanut, nut, and seafood allergies were never outgrown, it has become apparent that clinical tolerance develops in about 20% of young children with peanut allergy.[16,17] Recent studies from the United Kingdom and the United States indicate that the prevalence of peanut allergy has doubled in young children during the past decade[18,19] Children with atopic disorders tend to have a higher prevalence of food allergy; about 35% of children with moderate-to-severe atopic dermatitis have IgE-mediated food allergy,[20] and about 6% to 8% of asthmatic children have food-induced wheezing.[21] On the basis of these more recent surveys, 3.5% to 4% of the US population are believed to have IgEmediated food allergy.[22]

FACTORS ASSOCIATED WITH ELEVATED RISK OF FOOD ALLERGY:

Prenatal and postnatal factors have been studied.

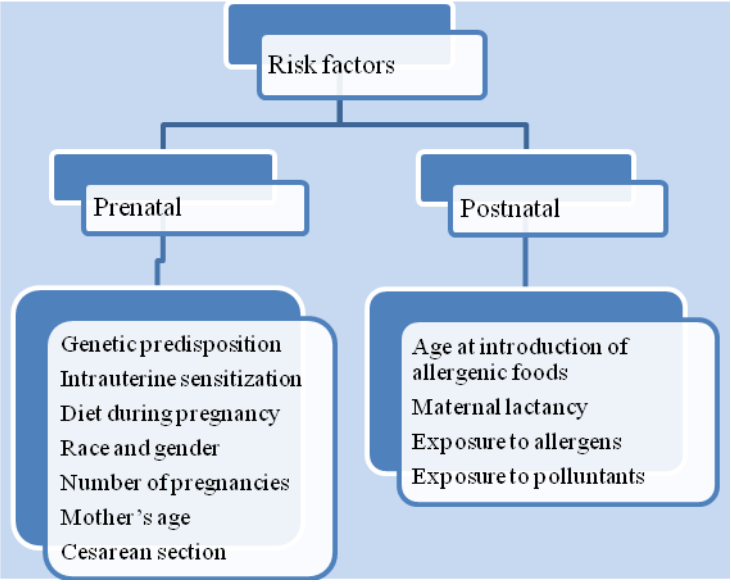

Figure 2: Various risk factors

Prenatal factors

Genetic predisposition

It is believed that in the same way there are genetic factors related to elevated risk of suffering other allergic diseases, there are also genetic factors that predispose to food allergy in individuals.

In the case of peanut allergy, a child has seven times more risk when having a parent or older brother with the same allergy.[23] A 64% greater risk is present in the case of monozygotic twins when a sibling or parent suffers this alteration.[24]The influence of genes HLA class II and an elevated rate of coincidence in monozygotic twins have been shown (64%), in comparison with dizygotic (7%) which indicate a strong genetic contribution in peanut allergy. A study showed association between nut allergy and polymorphism in a signal transducer and a transcript activator.[25] Besides, the risk of food allergy being four times greater in children with asthmatic parents has been proved, this in comparison to normal population.[26-28] This supports it being an inherit trait with a dominant genetic pattern, weather it be recessive or polygenetic, that is as pattern with variable expression. The risk of food allergy is greater in children born from parents with a strong family background of atopy. In the case of only one parent this corresponds to 50%, in both parents this is 70%. In brothers the risk of being affected is [25] times greater than the general public.[26] Japanese population trial showed association between gene IL-10 polymorphism and food allergy.[29] Another trial conducted in German population identified IL-13 polymorphism associated to this condition.[30-31]

Intrauterine sensitization

From week 11 in pregnancy small amounts of IgE are produced. In some cases an elevated number of IgE in the umbilical chord at the moment of birth (> 0.8 UI/ mL) and have been associated to a greater risk of allergies during their life. Protein caused intrauterine sensitization is suggested in the amniotic fluid, which pass through the baby's skin and in a lesser degree through aspiration.[32, 33]

A trial conducted in Vancouver[34] with high-risk children, identified before birth by having at least one parent with allergic disease, determined the concentration of IgE in the umbilical chord at moment of birth, with a follow through of 12 months. The authors found that the concentration of IgE is a significant predicting factor for food allergy urticaria.

Diet during pregnancy

The option of offering a low allergen diet in pregnant women is still under discussion. There are different postures and recommendations made by the American Pediatric Academy (AAP) and the European Society of Clinical Pediatric Allergy and Immunology (ESPACI).[23] The AAP does not recommend a diet during pregnancy with the only exception of excluding peanuts, while the ESPACI and the European Pediatric Gastroenterology Society, in a consensus review of prospective studies in children with high risk (at least one sibling –parent or sibling– with allergy), proved the protective effect different dietary programs have in the prevention of allergies in food allergy incidence, specially in milk protein.[35]

Birth through Cesarean section

This could be a food allergy risk factor, due to the colonization delay in the baby's intestines. In a sample of

2,803 live babies this factor was studied and what was observed was that those born from allergic mothers had seven times greater risk of allergy to egg, fish and nuts,[36] according to the observations by parents ($p = 0.005$) and four times greater risk of allergies from the same foods, based on the doctor's observations. In non-allergic mothers no significant differences where found between a Cesarean and a vaginal birth.

Male gender

Different studies have pointed out male gender being a risk factor in allergic diseases in general, but few assess the specific relation with food allergy. A prospective cohort study[37] made in With island

(UK) included patients in prenatal period and followed the babies from birth to the age of four years looking for environmental and genetic influence in the appearance of allergic manifestations, they conducted coetaneous tests positive to food allergies at the age of four with an incidence of 3.7 for boys and 1.9 for girls.

Postnatal factors

Maternal lactation

Prospective observational trials report that exclusively maternal lactation, for a period of three to six months, decreases the risk of allergy to milk protein and food allergy by the age of three.[38]

Saarinen and collaborators[39] conducted a prospective trial with followthrough to the age of three without intervention in non-selected children. They found that maternal lactation for a period of at least six months contributes to protection against food allergy. There is no doubt about the nutritional and immunologic importance of maternal lactation; however, the time it should be offered and the exclusiveness in breast-feeding the baby are the factors that influence in the appearance of allergies.

Diverse studies indicate that maternal lactation has a preventative effect compared to cow milk formula feeding.[40] Different metanalysis have shown that maternal lactation for a period of at least three months in babies with atopy inheritance is a protective factor against dermatitis atopy (OR 0.58) and recurrent wheezes in the first five years of age (OR 0.52).[41]

The only random prospective trial compared maternal milk formula to cow milk formula in a sample of premature patients, and found that the cow milk diet increased the risk of atopic dermatitis and allergy to milk protein by the age of 18 months, this specially in the group that had atopic inheritance.[42]

Other trial in children with atopic risk exclusively breast-fed for more than four months, with a delayed weans, had a significant allergic incidence reduction to cow milk and atopic dermatitis for the firs four years of their life.[43]This sustains that the introduction of milk formulas before weaning is related to a greater incidence of developing allergy to cow milk protein.[44]

Meanwhile the European Society of Clinical Pediatric Allergy and Immunology recommends the following:

- ✓ Maternal lactation during the firs four to six months of life can reduce the incidence of allergic manifestations and is highly recommended.
- ✓ Supplementary food should not be administered before five months of life.
- ✓ Children with atopy risk (parents or sibling) and fed with formula should take confirmed low allergenic formula, this reduces food and milk protein allergy incidence.

Weaning

Beginning weaning between four and six months of life has been related to a greater incidence of cow milk and food allergy, this based on prospective observational trials.

These being backed up by the European Society of Clinical Pediatric Allergy an Immunology and the American Pediatric Academy based on a weaning guideline that sustains the introduction of solid meals at a short age is associated with the induction of food allergy.[45] Independently, the American Pediatric Association suggests: Maternal feeding during the first year of life; weaning should not be started until the age of six months and introduction of milk until the age of twelve months, eggs and peanuts until two years, nuts and fish until three years. While the European Society of Clinical Pediatric Allergy an Immunology only suggests maternal lactation for four to six months, with weaning after five months of age.

Kajosaari and Saarinen1[23] observed that introducing meal before six months old is related to the increase of food allergies and atopic dermatitis during the first year of life. Fergusson and collaborators proved in a group of 1,210 children with a follow of ten years that weaning before six months of age is more frequently related to atopic dermatitis.[46] Wilson and his group observed in a group of 674 children with a follow up of one year that wheeze incidence are of greater incidence in children weaned before 15 weeks of age.[47] Some authors indicate variations as to when begin weaning: some indicate that after four months, others after six, which has demonstrated a similar reduction to cow milk and other food allergy by the first 18 months of life.

Underweight at birth

Diverse studies have pointed out that underweight at birth is a high risk factor in developing allergies, but there are no studies that relate this to food allergy in particular.[48]

Exposure to intra and extra-home allergens

Different tests have been made in order to know the effect of early age exposure to allergens associated to respiratory allergies, intra and extra-home[49,50] (asthma, rhinitis); however, no data exist that relate them with food allergies.

Exposure to environmental pollutants

Exposure to tobacco fumes (main indoor pollutant) has been studied as a risk factor in allergic diseases. There is significant association between parents smoking (specially mother), asthma and wheezes during infancy, [51, 52] but they are in no relation with food allergies.

FOOD INGREDIENTS AND FOOD ALLERGY

Many different types of food have been identified as allergens for some people. However, misinformation about allergic reactions to different food ingredients can sometimes cause unnecessary food avoidance. Current scientific knowledge about some of the most common ingredients is summarized below.

Food additives

Food additives have been used for many years for five main reasons: to maintain product consistency; to improve

or maintain nutritional value; to maintain palatability and wholesomeness; to provide leavening or control acidity and alkalinity; and to enhance flavor or impart desired color. Although most Americans consume a wide variety of food additives daily, only a small number have been associated with reactions. These reactions are not usually caused by an allergic response to the additive, but are examples of food intolerance.[53]

FD&C Yellow No. 5 (tartrazine)

FD&C Yellow No. 5 (tartrazine) is used to color beverages, candy and other foods. Scientists have concluded the color additive may cause hives in fewer than one out of 10,000 people.[54] There is no scientific evidence that FD&C Yellow No. 5 provokes asthma attacks or that people who react to aspirin have a cross-sensitivity to it, [55] as has been claimed in the past. Whenever FD&C Yellow No. 5 is added to foods, it must be listed on the product label. This allows the small portion of people who may be sensitive to FD&C Yellow No. 5 to avoid it.

Monosodium glutamate (MSG)

Monosodium glutamate (MSG) has been used for many years as a flavor enhancer. It is the sodium salt of glutamic acid, an amino acid found naturally in the human body and in all protein-containing foods such as cheese, vegetables, meat, and milk. The U.S. Food and Drug Administration (FDA) believes MSG is a safe food ingredient for the general population .[56] MSG is not an allergen and there is conclusive scientific evidence that MSG does not cause or exacerbate asthma.[57, 58] A small number of people may experience mild and transitory symptoms to MSG. However, these short-lived responses only occur in clinical settings upon ingestion of large doses of MSG without food, and were not reproduced in retesting. Whenever MSG is added to food, it is listed on the label as monosodium glutamate.

Sulfites

Sulfating agents are sometimes used to preserve the color of foods such as dried fruits and vegetables, and to inhibit the growth of microorganisms in fermented foods such as wine. Sulfites are safe for most people. A small segment of the population, however, has been found to develop shortness of breath or fatal shock shortly after exposure to these preservatives.[59] Sulfites can provoke severe asthma attacks in sulfite-sensitive asthmatics.[60] For that reason, in 1986 the FDA banned the use of sulfites on fresh fruits and vegetables (except potatoes) intended to be sold or served raw to consumers. Sulfites added to all packaged and processed foods must be listed on the product label.

APPROACHES FOR REDUCING ALLERGIC REACTIONS

1. DNA vaccines

Because they are not proteins and can't translate into proteins to become allergens in allergic persons, DNA vaccines can be used to reduce allergic reactions. DNA vaccines can be developed by one of three approaches: (i) using the naked DNA of allergens (ii) using hypoallergenic derivatives of allergen DNAs by modification of nucleotides; or (iii) fragmenting allergen DNA and fusing with ubiquitin, as fragmenting the antigen destroys its native structure[61].

2. Anti-IgE antibodies

Binding of IgE antibodies to specific high affinity receptors on basophils and mast cells triggers the release of histamine and other mediators that result in allergy symptoms. Thus developing anti-IgE antibodies against IgE could be a potential therapeutic option for allergy treatment[62].

3. Modification of the epitopes

Modification of IgE binding sites, i.e. epitopes of allergens, could be another approach to attenuate hypersensitivity reactions. Epitopes of allergens can be created by modifying allergens and their hypoallergic derivatives. Singh and Bhalla[63] have demonstrated that the anaphylactic potential of rye grass pollen can be reduced by introducing a few point mutations in their allergens before using them for immunotherapy. In the shrimp allergen tropomycin, eight IgE epitopes were identified and mutated. These mutations had no effect on their secondary structure (in other words, did not change the basic structure of the IgE) but the allergic response was reduced by 90-98%, so this mutant could be helpful for therapy[64].

4. Target mast cells and basophil cells

Another possible option to reduce IgE related hypersensitivity reaction is to directly kill the mast cells and basophils expressing high affinity receptors for IgE. Human originated apoptosis-inducing proteins can be used, as these will be less toxic or less immunogenic than the proteins produced in a different animal or plant[65].

5. Immunotherapy

Immunotherapy (biologic therapy) is indicated for people who are extremely allergic to specific allergens. Immunotherapy is done by gradually exposing the patient to lower doses of allergens to reduce the sensitization. It relies on the progressive production of the blocking antibody IgG and reduction in excessive production of IgE[2].

6. Reducing the allergenicity of food crops

Scientists are trying to develop methods to reduce plant allergenicity. Generally it is believed that environmental stress to plants due to pollution, fertilizers, pesticides, heavy metals, etc., reduces their vitality and makes them produce various defense molecules. [66]; these defense molecules could be active allergens[67].

ALTERATIONS IN ALLERGENICITY

Cooking and processing of foods can affect their allergenicity: Some foods, especially vegetables and fruits, become less allergenic when cooked. The allergenicity of many other foods is unaffected by heat and they cause the same degree of reaction whether eaten raw or cooked. Milk contains 30 potentially allergenic proteins, some of which are sufficiently changed by heating as to no longer cause an allergic reaction, while others are unaffected even by boiling. Whether a person can tolerate boiled milk or not depends on the specific proteins to which they are

sensitized: If a person is allergic to milk proteins that are denatured by heat (heat labile proteins) they will tolerate boiled milk, but not milk that has been insufficiently heated. When a person is sensitized to milk proteins that are unaffected regardless of whether it has been boiled or not boiled.

The method of cooking also seems to affect the allergenicity of some foods: For example, roasting peanuts, which is common in Western countries, tends to increase the allergenicity of the peanuts, whereas boiling or other methods of cooking, more common in Oriental countries, either reduces, or does not affect peanut allergenicity.

In addition, the ripeness of vegetables and fruits can affect their degree of allergenicity. During the ripening process the plant produces different components, some of which may be less or more allergenic that the unripe form. Thus it is often not possible to predict whether a fruit or vegetable will be less or more allergenic as it ripens. An interesting example of a change in the "reactivity potential" of a plant product is the tomato. In this case it appears that it is the histamine content of the fruit that changes, not the protein. The green tomato rarely causes symptoms in a histamine-intolerant person, whereas the ripe fruit does cause a reaction. Tomatoes release histamine during the process of ripening. Although this is not, strictly speaking, an example of a change in allergenicity, it is a very good illustration of how a food in one stage of maturation causes symptoms, but in a later stage does not.

CROSS-REACTIONS BETWEEN FOOD AND ENVIRONMENTAL ALLERGENS:

Cross-reactions are frequently observed between pollens and certain foods, especially fruits and vegetables[68, 69]. This is the oral allergy syndrome, which typically involves mild reactions as previously mentioned. Examples include cross-reactions between birch pollen and apples, ragweed pollen and melons, and mugwort pollen and celery[68-70]. Cross-reactions have also been noted between latex allergies, a common problem among health-care workers, and certain foods including bananas, kiwis, avocados, and chestnuts.

CONCLUSION

Allergy is one of the most widespread diseases of the modern world. More than 25% of the population in industrialized countries suffers from allergies. Food allergies and other food sensitivities are individualistic adverse reactions to foods. The prevalence of cows' milk allergy among infants under the age of two has been studied and found to be approximately 2% in all three countries in well-conducted clinical studies involving groups of unselected infants followed from birth to the age of two years. Eggs and peanuts are also common allergenic foods for infants, along with soybeans, tree nuts, fish, and wheat. Among adults peanuts are probably the most common allergenic food. Eight foods or food groups are thought to account for more than 90% of all IgE-mediated food allergies on a worldwide basis. DNA vaccines can be used to reduce allergic reactions. Modification of IgE binding sites could be another approach to attenuate hypersensitivity reactions.

REFERNECES

1. Valenta R, The future of antigen specific immunotherapy of allergy, Nature Reviews Immunology, 2002, 2, 446-453.
2. Suri S, ABC's Of Allergies, CSA Discovery Guides, 2006, 1-12.
3. Kondo Y, Urisu A, Tokuda R, Identification and Characterization of Allergens in the Tomato Fruit by Immunoblotting, International Archives of Allergy and Immunology, 2001, 126, 294-299.
4. Alenius H, Kalkkinen N, Reunala T, Palosuo T, The main IgE-binding epitope of a latex allergen, prohevein, is present in its N-terminal 43-amino acid fragment, hevein, The Journal of Immunology, 1996, 156, 1618-1625.
5. Bohle B, Wagner B, Vollman U, Buck D, Niggemann B, Szepfalusi Z, Fischer G, Scheiner O, Breiteneder H, Ebner C, The Journal of Immunology, 2000, 164, 4393-4398.
6. Drew AC, Nirupama PE, Kenins L, de Silva HD, Suphioglu c, Rolland JM, O'Hehir RE, Hypoallergenic variants of the major latex allergen Hev b 6.01 retaining human T lymphocyte reactivity, The Journal of Immunology, 2004, 173, 5872-5879.
7. Thien VD, Elsayed S, Florvaag E, Hordvik I, Endresen C, Allergy to fish: parvalbumins: Studies on the cross-reactivity of allergens from 9 commonly consumed fish, Journal of Allergy and Clinical Immunology, 2005, 116(6), 1314-1320.
8. Food allergy in children and young people, NICE Clinical Guideline (February 2011)
9. Food and Agriculture Organization (FAO). Report of the FAO Technical Consultation on food allergies. Rome, Italy. November 13-14, 1995.
10. Sampson HA, Food hypersensitivity: manifestations, diagnosis, and natural history. Food Te c h n o l o g y. 46: 41-144, 1992.
11. Novembre E, de Martino, M., Vierucci, A. Foods and respiratory allerg y. J Allergy Clin. Immunol. 81:1059-65, 1988.
12. Sampson, H.A., Mendelson, M.D., Rosen, J.P. Fatal and nearfatal anaphylactic reactions to food in children and adolescents. New Engl. J. Med. 327:380-4, 1992.
13. "Other atopic dermatitis and related conditions".*ICD9*.
14. Bock SA. Prospective appraisal of complaints of adverse reactions to foods in children during the first 3 years of life. Pediatrics 1987; 79: 683-8.
15. Host A, Halken S, Jacobsen HP, Eastmann A, Mortensen S, Mygil S. The natural course of cow's milk protein allergy/intolerance [abstract]. J Allergy Clin Immunol 1997; 99(suppl):S490.
16. Hourihane JO'B, Roberts SA, Warner JO. Resolution of peanut allergy: case-control study. BMJ 1998; 316:1271-5.
17. Skolnick HS, Conover-Walker MK, Koerner CB, Sampson HA, Burks W, Wood RA. The natural history of peanut allergy. J Allergy Clin Immunol 2001; 107:367-74.
18. Grundy J, Bateman BJ, Gant C, Matthews SM, Dean TP, Arshad S. Peanut allergy in three year old children—a population based study [abstract]. J Allergy Clin Immunol 2001; 107(suppl):S231.
19. Sicherer SH, Munoz-Furlong A, Sampson HA. Prevalence of peanut and tree nut allergy in the United States determined by means of a random digit dial telephone

survey: a 5-year follow-up study. J Allergy Clin Immunol 2003; 112:1203-7.
20. Eigenmann PA, Sicherer SH, Borkowski TA, Cohen BD, Sampson HA. Prevalence of IgE-mediated food allergy among children with atopic dermatitis. Pediatrics 1998; 101:e8.
21. Novembre E, de Martino M, Vierucci A. Foods and respiratory allergy. J Allergy Clin Immunol 1988; 81:1059-65.
22. Munoz-Furlong A, Sampson HA, Sicherer SH. Prevalence of self reported seafood allergy in the U.S. [abstract]. J Allergy Clin Immunol 2004; 113(suppl):S100.
23. Hourihane JO, Dean TP,Warner JO. Peanut allergy in relation to heredity, maternal diet, and other atopic diseases: results of a questionnaire survey, skin prick testing, and food challenges. BMJ 1996; 313:518-21.
24. Sicherer SH, Furlong TJ, Maes HH, Desnick RJ, et al. Genetics of peanut allergy: a twin study. J Allergy Clin Immunol 2000; 106:53-56.
25. Amoli MM, Hand S, Hajeer AH, Jones KP, et al. Polymorphism in the STAT6 gene encodes risk for nut allergy. Genes Immun 2002; 3:220-4.
26. American College of Allergy, Asthma, and Immunology. Food allergy a practice parameter. Ann Allergy Asthma Immunol, 2006(3 Suppl. 2); 96:S1-68.
27. Wahn U, von Mutius E. Childhood risk factors for atopy and the importance of early intervention. J Allergy Clin Immunol, 2001; 107:567-74.
28. Hendrik N, Vibeke B, Celeste P. Environmental factors as a cause for the increase in allergic disease. Ann Allergy Asthma Immunol 2001; 87(Supp. 1):7-11.
29. Campos-Alberto EJ, Shimojo N, Suzuki Y, Mashimo Y, et al. IL-10 gene polymorphism, but not TGF-beta1 gene polymorphisms, is associated with food allergy in a Japanese population. Pediatr Allergy Immunol 2008; 19:716-21.
30. Liu X, Beaty TH, Deindl P, Huang SK, et al. Associations between specific serum IgE response and 6 variants within the genes IL4, IL13, and IL4RA in German children: the German Multicenter Atopy Study. J Allergy Clin Immunol 2004; 113:489-95.
31. Lack G. Epidemiologic risks for food allergy. J Allergy Clin Immunol 2008; 121:1331-6.
32. Bjorkstén B, Jjellman B, Zeiger R. Development and prevention of allegic disease in childhood. In: Middleton E, Reed C, Ellis E, Adkinson F, et al, editors. Allergy principles and practice. 5th ed. St Louis: Mosby 2003; pp: 816-37.
33. Annesi-Maesano I, Pollitt R, King G, Bousquet J, et al. In utero exposure to lead and cord blood total IgE. Is there a connection? Allergy 2003:58:589-94.
34. Kaan A, Dimich-Ward H, Manfreda J, Becker A, et al. Cord blood IgE: its determinants and prediction of development of asthma and other allergic disorders at 12 months. Ann Allergy Asthma Immunol 2000; 84:37-42.
35. Muraro A, Dreborg S, Halken S, Host A, et al. Dietary prevention of allergic diseases in infants and small children. Part III: Critical review of published prereviewed observational and interventional studies and final recommendations. Pediatr Allergy Immunol 2004; 15:291-307.
36. Eggesbo M, Botten G, Stigum H, Nafatad P, Magnus P. Is delivery by cesarean section a risk factor for food allergy? J Allergy Clin Immunol 2003; 112:420-6.
37. Tariq S, Matthews SM, Hakim EA, Stevens M, et al. The prevalence of and risk factors for atopy in early childhood: a whole population birth cohort study. J Allergy Clin Immunol 1998:101:587-93.
38. Halken S. Prevention of allergic disease in childhood: clinical and epidemiological aspects of primary and secondary allergy prevention. Pediatric Allergy Immunol 2004; 15(Suppl. 16):9-32.
39. Saarinen UM, Kajosaari M, Backman A, Siimes MA. Prolonged breast-feeding as prophylaxis for atopic disease. Lancet 1979; 2:163-6.
40. Schoetzau A, Filipiak-Pittro B, Koletzko S, von Berg A, et al. Effect of exclusive breast-feeding and early solid food avoidance on the incidence of atopic dermatitis in high-risk infants at 1 year of age. Pediatr Allergy Immunol 2002; 13:234-42.
41. Bloch AM, Mimouni D, Mimouni M, Gdalevich M. Does breastfeeding protect against allergic rhinitis during childhood? A meta-analysis of prospective studies. Acta Paediatr 2002; 91:275-9.
42. Lucas A, Brooke OG, Morley R, Cole TJ, Bamford MF. Early diet of preterm infants and development of allergic or atopic disease: randomized prospective study. BMJ, 1990, 300, 837- 40.
43. Halken S, Hansen KS, Jacobsen HP, Estmann A, et al. Comparison of a partially hydrolyzed infant formula with two extensively hydrolyzed formulas for allergy prevention: a prospective, randomized study. Pediatr Allergy Immunol 2000; 11:149-61.
44. Høst A, Husby S, Østerballe O. A prospective study of cow's milk allergy in exclusively breast-fed infants. Acta Paediatr Scand, 1988; 77:663-70.
45. Fiocchi A, Assa´ad A, Bahna S, Adverse Reactions to Foods Committee, et al. Food allergy and the introduction of solid foods to infants: a concensus document. Ann Allergy Asthma Hidalgo-Castro EM et al, Immunol 2006; 97:10-21.
46. Fergusson DM, Horwood LJ, Shannon FT. Early solid food feeding and recurrent childhood eczema: a 10-year longitudinal study. Pediatrics 1990; 86:541-6.
47. Wilson AC, Forsyth JS, Greene SA, Irvine L, et al. Relation of infant diet to childhood health: seven year follow up of cohort of children in Dundee infant feeding study. BMJ 1998:316:21-25.
48. O´Connell EJ. Pediatric allergy: a brief review of risk factors associated with developing allergic desease in childhood. Ann Allergy Asthma Immunol 2003; 90(Suppl. 3):53-58.
49. Melen E, Wickman M, Nordvall SL, Hage-Hamsten M, Lindfors A. Influence of early and current environmental exposure factors on sensitization and outcome of asthma in pre-school children. Allergy 2001; 56:646-52.
50. Lau S, Illi S, Sommerfeld C, Niggemann B, et al. Early exposure to house-dust mite and cat allergens and development of childhood asthma: a cohort study. Lancet 2000; 356:1392-7.
51. Strachan DP, Cook DG. Parental smoking and childhood asthma: longitudinal and case-control studies. Thorax, 1998, 53:204-12.
52. Tager IB. Smoking and childhood asthma-where to we stand? Am J Respir Crit Med 1998; 158:349-51.
53. Ta y l o r, S.L., Hefle, S.L., Gauger, B.J. Food allergies and sensitivities. In Helferich W, Winter, CK, eds. Food tox i c o l o g y. Boca Raton, CRC Press; 2000:1-36.
54. Murdoch D, Pollock I, Young E, Lessof MH, Food additive induced urticaria: studies of mediator release during provocation tests. J. Royal College Phys. 4:262-6, 1987.
55. Stevenson DD, Simon RA, Lumry, W.R., Mathison, D.A. Adverse reactions to tartrazine. J. Allergy Clin. Immunol. 78:182-91, 1986.
56. Federation of American Societies for Experimental Biology (FASEB). Analysis of Adverse Reactions to Monosodium Glutamate (MSG). Prepared by the Life Sciences Research Office, FASEB, for the Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration, Bethesda, Maryland: FASEB, 1995.

57. Wo e s s n e r, K.M., Simon, R.A. Monosodium glutamate. In Metcalfe, DD, Sampson, HA, Simon, RA, eds. Food Allerg y: Adverse Reactions to Foods and Food Additives (2nd edition). Cambridge, MA, Blackwell Science, 2000:359-363.
58. Woods, R.K., We i n e r, J., Thien, F., Abramson, M. & Walters, E.H. Respiratory pathophysiologic responses: The effects of monosodium glutamate in adults with asthma who perceive themselves to be monosodium glutamate-intolerant. J. Allergy Clin. Immunol, 101(6): 762-771, 1998.
59. Simon, R.A. Sulfite challenge for the diagnosis of severity. A l l e rgy Proceedings 10:357-62, 1989.
60. Bush, R.K., Ta y l o r, S.L., Holden, K., Nordlee, J.A., Busse, W. W. The prevalence of sensitivity to sulfiting agents in asthmatics. Am. J. Med. 81:816-20, 1986.
61. Hartl A, Weiss R, Hochreiter R, Scheiblhofer S, bauer R, valenta R, leitner W Thalhamer J, Strategies for the development of safe and effective DNA vaccines for allergy treatment, 2003, 94, 279-98.
62. Rudolf MP, Zuercher AW, Nechansky A, Ruf C, Vogel M, Miescher SM, Stadler M, Kricek F, Molecular Basis for Nonanaphylactogenicity of a Monoclonal Anti-IgE Antibody, The Journal of Immunology, 2000, 165, 813- 819.
63. Singh MB, Bhalla PL, Hypoallergenic derivatives of major grass pollen allergens for allergy vaccination, Immunology and Cell Biology, 2003, 81, 86.
64. Reese G, Viebranz J, Leong-Kee SM, Plante M, Lauer I, Randow S, Moncin MSM, Ayuso R, Lehrer SB, Vieths S, Reduced allergenic potency of VR9-1, a mutant of the major shrimp allergen Pen a 1 (tropomyosin), The Journal of Immunology, 2005, 175, 8354-8364.
65. Belostotsky R, Galski HL, Apoptosis- Inducing Human-Origin Fce-BaK Chimeric Proteins for Targeted Elimination of Mast Cells and Basophils: A new Approach for Allergy Treatment, The Journal of Immunology, 2001,167, 4719-4728.
66. Thi DB, Food allergy, environment and primary and secondary prevention of atopic dermatitis, Ann Dermatol Venereol, 2005, 132.
67. Uguz A, Lack G, Pumphrey R, Ewan P, Warner J, Dick J, Briggs D, Clarke S, Reading D, Hourihane J, Allergic reactions in the community: a questionnaire survey of members of the anaphylaxis campaign, Clin Exp Allergy, 2005, 35(6), 746-750.
68. Ballmer-Weber BK, Vieths, S., Luttkopf, D., Heuschmann, P., and Wuthrich, B. 2000. Celery allergy confirmed by double-blind, placebo-controlled food challenge: A clinical study in 32 subjects with a history of adverse reactions to celery root. J. Allergy Clin. Immunol. 106(2): 373-378.
69. Calkoven, PG, Aalbers, M., Koshte, V.L., Pos, O., Oei, H.D., and Aalberse, R.C. 1987. Cross-reactivity among birch pollen, vegetables and fruits as detected by IgE antibodies is due to at least three distinct cross-reactive structures. Allergy 42: 382-390.
70. Van Ree, R. and Aalberse, R.C. 1993. Pollen-vegetable food crossreactivity: Serological and clinical relevance of crossreactive IgE. J. Clin. Immunoassay 16: 124- 130.