

Reviews

Environmental exposure to peanut and the risk of an allergic reaction



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Key Messages

- Data have shown that peanut butter vapors and smeared peanut butter on skin do not cause systemic reactions; that peanut can be abated from hands and surfaces using appropriate cleaning agents; and that shelled peanut dust does not become airborne.
- Recent data have suggested that a dose of 1.5 mg of peanut protein would be generally tolerated by approximately 95% of the peanut-allergic population based on objective symptoms in challenge-based studies.
- Restrictive policies that focus on bans (or restricted presence in certain areas) of peanuts or peanut-containing products in environments such as schools or on commercial aircraft are not backed by evidence that such measures work.

ARTICLE INFO

Article history:

Received for publication January 5, 2018.

Received in revised form March 7, 2018.

Accepted for publication March 12, 2018.

ABSTRACT

Objective: To review the evidence of the risk of environmental exposure to peanut to a peanut allergic individual.

Data Sources and Study Selection: A narrative review was performed using a PubMed search of relevant articles involving peanut environmental distribution, environmental peanut abatement, and public policy regarding peanut restriction.

Results: Data from 4 studies have shown that peanut butter vapors and smeared peanut butter on skin do not cause systemic reactions, that peanut can be abated from hands and surfaces using appropriate cleaning agents, and that shelled peanut dust does not become airborne. Studies have recently confirmed dose of 1.5 mg of peanut protein would be generally tolerated by approximately 95% of the peanut-allergic population based on objective symptoms in challenge-based studies, affirming earlier research. Restrictive policies that focus on bans (or restricted presence in certain areas) of peanuts or peanut-containing products in environments such as schools or on commercial aircraft are not backed by evidence that such measures work, which may raise an uncomfortable clash between accommodations that lack any medical evidence of necessity and a desire to provide measures that comfort our patients.

Conclusion: There is little risk posed from non-oral exposure to peanut in the environment, from casual contact, proximity, or inhalation. If 5% of the population may tolerate a threshold of approximately 1.5 mg of peanut protein, this may help liberate behavior and situational-decision making regarding the necessity of certain avoidances and restrictions. Continued work is needed to dispel myths about the mechanisms of how peanut may induce an allergic reaction.

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Disclosures: Dr Greenhawt has served as a consultant to the Government of Canada regarding the risk of peanut, tree nut, and seed allergy and commercial air travel and has received honorarium from state, national, and international allergy organizations for lectures on this topic; serves as a non-financially compensated member of the Scientific Advisory Council for the National Peanut Board; is an expert panel and coordinating committee member of the NIAID-sponsored Guidelines for Peanut

Allergy Prevention; has served as a consultant for the Canadian Transportation Agency, Thermo Fisher, and Aimmune Therapeutics; is a member of physician/medical advisory boards for Aimmune Therapeutics, DBV Technologies, Nutricia, Kaleo Pharmaceutical, Nestle, and Monsanto; is a member of the scientific advisory council for the National Peanut Board; has received honorarium for lectures from the Allergy and Asthma Network, Thermo Fisher, and multiple state allergy societies, the ACAAI, the EAACI, and the CSAI; is an associate editor for the *Annals of Allergy, Asthma, and Immunology*; and is a member of the Joint Taskforce on Allergy Practice Parameters. **Funding Sources:** Agency for Healthcare Research and Quality (grant 1K08HS024599-01).

Introduction

Peanut allergy is a growing public health concern in Westernized countries, affecting 1% to 4.5% of the population.^{1–4} Reactions can be severe, but such severity is poorly predicted, and individuals with allergy and their caregivers often live with an ongoing burden of disease that can result in a state of hypervigilance and concern for safe accommodation to avoid unintended ingestion.^{2,5} There has been increased focus on the safety for an individual with peanut allergy to be in proximity to peanut in public venues such as schools or child care centers and commercial aircraft, because of the perception these individuals are at risk of airborne exposure, contact exposure, and/or unintended ingestion.^{6–10} To date, there is no supporting evidence that peanut or peanut dust becomes airborne or that inhaling vapors from peanut butter triggers reaction. Thus, making accommodations for individuals with peanut allergy based on such presumed risk is controversial or contentious, because their necessity is not supported by current medical evidence demonstrating that such a risk exists. In schools, accommodations have frequently been initiated under broad interpretations of federal disability laws, which have been used to stipulate a right to accommodation for a child with food allergy, although not what particular accommodation should be made.¹¹ Canada is the only government that has instituted any legal requirements regarding public accommodation for flying with a peanut allergy, which are restricted to passage on Air Canada.¹² In the United States, a public law expressly forbids any similar governmental policy or expenditure.¹³

The purpose of this review is to detail the medical evidence concerning the potential risk of reaction to peanut in public venues, focusing on educational settings and commercial aircraft, and to review the medical evidence and best practices regarding potential risk-mitigating strategies.

Public Exposure to Peanut, Tree Nut, and Sesame Seed and Risk of Reaction From Inhalation or Contact With Allergen

There has been an increasing concern regarding the risk of exposure to peanut and reactions occurring in public venues, with focus on peanut-restricted venues pertaining to educational facilities and commercial aviation.⁶ This has been further segmented toward protection against the risk of proximity exposure to peanut dust or shell fragments, peanut butter, and products with trace or precautionary labeling for peanut based on belief regarding perceived danger of inhalational reactions or contact exposures. Data have consistently shown that (1) peanut dust does not aerosolize; (2) peanut butter vapors contain no protein; (3) surfaces can be effectively abated of residue; and (4) skin contact might cause local irritation but not systemic reactions. Thus, the risk of reaction in public from casual exposure is low, except in instances when peanut is directly ingested.^{14–16}

What Is the Risk Posed by Direct Casual Environmental Contact With and Inhalation of Peanut Butter?

In 2004, Simonte et al¹⁴ explored the risk of casual environmental contact with, and smell of, peanut butter by mimicking proximity exposures that could be encountered in the classroom or lunch room setting. Twenty-nine patients with severe peanut allergy, all with reported histories of inhalational or skin contact triggered reactions, underwent double-blinded inhalation challenge to 3 oz of peanut butter (or soy butter as the placebo) held 12 inches from the nose and masked for smell. For contact exposure, 0.2 mL of masked peanut butter or soy butter was directly smeared on the skin for 1 minute and then removed. In the 2 experiments, no subjects demonstrated any systemic allergic reaction from inhalational

exposure or skin contact, including changes in forced expiratory volume in 1 second. Three patients developed localized erythema, 5 had local pruritus from the peanut butter skin contact, and 5 developed erythema attributable to soy butter skin contact, demonstrating the irritant nature of “butters” applied to skin and the self-limiting nature of localized contact-induced symptoms. The investigators concluded that casual contact with or inhalation of peanut butter was highly unlikely to cause any symptoms, including generalized reactions, debunking that such exposures are a potential danger.¹⁴

Is There Similar Risk From Environment Exposure to Peanut Dust?

Perry et al¹⁵ investigated whether 5 mL of smeared peanut butter could be abated from tabletops, counters, desks, water fountains, and from one's hand and whether they could provoke dust circulation to simulate inhalational exposure (measuring Ara h 1) by shelling bags of peanuts and then walking on the shells. Dish soap did not remove smeared peanut butter from tabletops, but commercial agents such as Formula 409 (Clorox, Oakland, California), Lysol (Reckitt Benckiser LLC, Parsippany, New Jersey), and Target brand cleaner (containing bleach; Target Corp, Minneapolis, Minnesota) did. Neither water alone nor alcohol-gel based sanitizer removed peanut butter from hands, but Tidy Tykes wipes (Proctor and Gamble, Cincinnati, Ohio), Wet Ones (Edgewell, North Bergen, New Jersey), and liquid and bar soap did. Furthermore, no airborne peanut was detected in filters worn at the level of the neck after peanuts were shelled and then walked on in a small room, with and without air ventilation. From these data, it was determined that peanut can effectively be abated from the skin and common surfaces with multiple agents and that peanut dust could not be detected in the air.¹⁵

Brough et al¹⁶ replicated such findings in homes of peanut-consuming families using a highly sensitive polyclonal enzyme-linked immunosorbent assay. Participants refrained from washing their bed sheets or vacuuming the house for 5 days, and investigators assayed for peanut in dust samples and surface wipes in several areas within the homes. Laminate and wood tables smeared with peanut butter and then vigorously cleaned with 6 circular swipes of a paper towel containing a standard commercial cleaning detergent held levels of peanut just above the assay's detectable threshold (<0.2 µg), but granite was effectively cleaned to undetectable levels. Sofa covers with peanut dust had 1,000-fold decrease in measurable peanut after a routine washing machine cycle. Peanut was detected in saliva and on tongue wipes 6 hours after consumption and mouth rinsing, at 3.34 and 0.39 µg/mL, respectively.

Airborne levels were tested in the following ways using a standard airborne sampler run at 2 L/min:

1. At 1 cm and 1 m above a jar of peanut butter and dry roasted peanuts for 22 hours
2. Above a pan of cooking peanut satay sauce containing 10 g of peanut for 10 minutes
3. On a volunteer's clothing, on the table, and breathed on for 10 minutes while eating peanut butter and dry roasted peanut
4. Continuously run for 22 hours in homes of high peanut consumers
5. At 1 cm and 1 m while peanut was being deshelled

At 1 cm and 1 m above a field with active peanut shelling, 331 and 4.7 µg/m³ (lower limit of detection 2.5 µg) of peanut were noted, respectively. However, as soon as the shelling was ceased, no residual levels were noted at either height.¹⁶

Putting the Environmental Experiments in Perspective

These data would imply that peanut products likely could be detected on a tray table, common surface, seat, and floors if these areas were not cleaned, but also suggest an exceptionally low likelihood of airborne distribution.^{15,16} The particles rapidly fall to the surface below the area of consumption without circulation. The residual amounts of peanut detected were believed to be a function of using an exquisitely sensitive probe. No study has demonstrated that such residual levels can trigger a reaction. Although Brough et al^{16,17} observed basophil activation in a handful of samples with 1 ng/mL of peanut, they stated this activity would not likely cause clinical allergy but would merely act as a driver for peanut sensitization in a child with eczema and a disrupted skin barrier.

Is There a Threshold Level of Ambient Residual Exposure Above Which a Reaction Is Likely?

Threshold levels are crucial in assessing risk of reaction for patients. A threshold is the level of exposure to an allergen that would be tolerated by a susceptible individual before an allergic reaction would be triggered.^{18,19} Such research is considered somewhat controversial, because it subverts the principle of “strict avoidance.”^{20,21} A 2013 survey conducted by a food allergy advocacy group within their membership noted that 82% to 90% of more than 30,000 respondents indicated they would never purchase products labeled “may contain” or made on “shared equipment” with their allergen, 82.9% reported they were unsure or would not buy a product even if it were below their child’s threshold and assumed “absolutely safe,” and 93% would not buy products below their child’s threshold even if any resulting reaction would be only “mild.”²²

Harmless exposure to trace allergen levels likely occurs frequently, demonstrating some threshold must exist.²³ Clinical thresholds are defined at a population level called the eliciting dose (ED), with focus on levels at which 1%, 5% (ED₅), and 10% of individuals with allergy might react.²⁴ Studies examining trace contamination in packaged goods in the United States and United Kingdom have noted that most exposure to such levels occurs well below a predicted ED₅ (eg, where 95% of the population would tolerate exposure) but noted a wide range of potential contamination in commercial products, ranging from 3 to 15,000 parts per million (ppm).^{25–27} A ppm is 1 mg of allergen weight per kilogram of package weight and represents approximately 2 L of water in an Olympic (50-m) size swimming pool (~660,000 gallons of water).²⁸

Two European studies using double-blinded placebo-controlled challenges noted an ED₅ for objective symptoms at 1.56 mg of peanut, although subjective symptoms were seen at 0.14 mg, demonstrating the difficulty in defining true vs perceived symptoms. A second study noted an ED₅ of 1.95 mg for peanut.^{29,30} A recent 5-center European study noted an ED of 10% for objective symp-

toms of peanut allergy at 2.8 mg of protein, although subjective symptoms were seen at 0.002 mg.³¹ A multicenter international study using a unique “1-shot” protocol validated the peanut ED₅ of 1.5 mg in 378 subjects, with just 8 (2.1%) mild reactions during an open oral food challenge in total. Quality of life in those tolerant of the 1.5-mg exposure increased significantly from baseline.³²

These data show a potential threshold dose for exposure likely exists. It is unclear how this might translate to environmental exposures, in particular, alleged peanut inhalational exposures or residual hand-to-mucosal membrane contact with a contaminated surface. However, this likely implies that relatively large amounts would be required to trigger an objective event and should reinforce the security provided by the aforementioned abatement evidence. Thus, even contact with cleaned surfaces holding a residual quantity of peanut or being in proximity of someone actively shelling peanut, these tiny quantities noted would be highly unlikely to provoke objective symptoms in the vast majority of patients.^{29,31,32} However, it is important to underscore that these data need further replication in larger samples that can produce tighter confidence intervals.

Rectifying Policy and Environmental Risk Data

Airline Reactions and Current Policy

The absolute incidence or prevalence of in-flight food allergic reactions is difficult to quantify given the number of reports compared with the estimated total number of passenger enplanements and these reports are almost exclusively subjective and self- or proxy-reported.¹⁰ This complicates accurately attributing causality in a defined trigger and route of exposure. An example of this are reported events attributed to inhalational or contact routes of exposure, which lack mechanistic sustenance and likely obscure other exposure routes (or triggers) that might not have been considered as the true provoking cause.

There are important commonalities from the 4 known studies of self-reported in-flight reactions (Table 1). These note high rates of reported events attributed to allergen inhalation, reported events resulting in symptoms meeting criteria consistent with anaphylaxis, poor reported epinephrine use, and limited flight crew involvement in assisting with a reaction.^{7–10} No in-flight research is possible to better define this epidemiology, given Congressional legislation (Public Law 106–69) preventing governmental funding for research into in-flight allergic reactions until a peer-reviewed scientific study demonstrated that circulating allergen is detectable and causes harm to patients with allergy.¹³ As such, only 1 study attempted to look at risk factors associated with reaction mitigating factors, which was limited to denoting an association between the report of a specific request or behavior and the report of not having an in-flight reaction, without verification, that (1) the ac-

Table 1
Comparison of Patient and Reaction Characteristics of Passenger-Reported Allergic Reactions to Peanut, Tree Nut, and Sesame Seed Occurring on Commercial Aircraft^{7–10}

Study	N	Age	Peanut	Inhalation	Contact	Ingestion	Severe	Epinephrine	Antihistamine
Sicherer et al (1999) ⁷	42	6 mo–50 y	35 (83.3%)	14 (33.3%)	7 (16%)	14 (33%)	5 (12%)	6 (14.3%)	28 (66.7%)
Comstock et al (2008) ⁹	41	2–50 y	30 (71%)	26 (58%)	4 (9%)	15 (33%)	36 (88%)	4 (9.7%)	15 (36.5%)
Greenhawt et al (2009) ⁸	150	6 mo–60 y	96 (64.1%)	73 (48.6%)	42 (27.9%)	24 (15.7%)	50 (33.3%)	15 (10%)	115 (77%)
Greenhawt et al (2013) ¹⁰	347	3 mo–50 y	239 (69.5%)	155 (44.7%)	114 (32.9%)	45 (13%)	not calculated	46 (13.3%)	297 (85.6%)
Study	Comorbid asthma	Respiratory	Cardiovascular	Skin	GI	Notified crew	Pre-notified airline	Had own medication	
Sicherer et al (1999) ⁷	17 (40%)	11 (31.4%)	0	15 (43%)	2 (6%)	14 (33%)	17 (40%)	27 (64.3%)	
Comstock et al (2008) ⁹	28 (68%)	NA	NA	NA	NA	12 (29%)	NA	12 (38%)	
Greenhawt et al (2009) ⁸	74 (53%)	42 (28%)	2 (1.4%)	84 (56%)	11 (7.5%)	67 (44%)	96 (63%)	115 (76%)	
Greenhawt et al (2013) ¹⁰	not reported	287 (82.7%)	77 (22.2%)	290 (83.6%)	84 (24.2%)	177 (51%)	193 (55.5%)	309 (88.9%)	

Abbreviations: GI, gastrointestinal; NA, not available.

Table 2
Adjusted Risk-Reduction Odds Associated With Reported Passenger Accommodations¹⁰

Lower odds of reaction	OR ^a (95% CI ^b)	No association	OR ^a (95% CI ^b)
Make any request	0.32 (0.19–0.54)	before boarding	0.81 (0.55–1.19)
Request buffer zone	0.64 (0.44–0.94)	sit in particular seat/section	0.62 (0.36–1.08)
Request announcement to not eat peanut/nut items	0.67 (0.46–0.96)	not distribute peanut/nut containing snacks	0.78 (0.56–1.08)
Request peanut/nut free meal	0.43 (0.28–0.65)	wipe seat belt	0.85 (0.61–1.2)
Wipe tray table	0.61 (0.44–0.86)	wipe seat back	0.8 (0.57–1.12)
Bring own food	0.19 (0.13–0.27)	wipe arm rest	0.73 (0.52–1.03)
Avoid use of airline blanket/pillow	0.67 (0.48–0.94)	wipe common surfaces	0.76 (0.52–1.13)

Abbreviations: CI, confidence interval; OR, odds ratio.

^aOdds of an event occurring or not occurring; OR > 1 indicates increased chance, OR < 1 indicates decreased chance, OR = 1 indicates no increased or decreased chance.

^bRange of values between which, with 95% probability, the true value is expected to fall. The *P* is the probability that the value is obtained by chance alone; *P* < .05 is the threshold for statistical significance.

commodation was actually granted or (2) that the accommodation for the allergy, if granted, influenced the outcome against the low statistical probability that an in-flight reaction could occur¹⁰ (Table 2).

Some airlines have voluntarily adopted food allergy accommodations, mainly geared to peanut and tree nut. Several airlines have voluntarily elected to not distribute items containing peanut or tree nut in flight or will do so upon request from a passenger with allergy, but this is strictly voluntary and non-enforceable. US airlines specifically do not promote outright peanut bans as policy. A very limited number of carriers might create up to a 3-row buffer zone in front and behind a passenger identifying himself or herself as allergic to peanut on request.³³ This particular strategy is mandated of Air Canada (1 row).³⁴ However, buffer zones have no proof of efficacy and might actually not provide any protection on closer inspection of cabin airflow dynamics and how human movement affects these (eSupplement).^{34–36}

School Reactions and Current Policy

School reactions are better studied than in-flight reactions. Approximately 18% of children with food allergy have been reported to have experienced a reaction at school, and 1 study noted 25% of first-time anaphylactic reactions from all causes (including adult reactions) occurred at school, indicating that school reactions are an issue requiring addressing.^{1,37} As of 2017, 49 of 50 states passed school stock epinephrine laws (most providing an option vs a mandate to stock epinephrine), but fewer than 25% of states have any formal food allergy management guidelines.^{38,39} The Centers for Disease Control and Prevention (CDC) published voluntary school food allergy management guidelines in 2013, which some states might use, but the effectiveness of these or any guidelines is unclear, as is their degree of potential variation.^{37,40–42} Although popular with some caregivers and advocates, no state guidelines or allergy professional societies advocate allergen bans as a strategy to accommodate peanut or any allergen in school. Such restrictive policies result from voluntary enactment by the school or as part of Section 504 of the Rehabilitation Act, a federal disability law that has often been interpreted to consider children with food allergy as disabled and entitled to accommodation for their food allergy to be able to attend school. A medical provider might or might not participate in the Section 504 plan hearing.¹¹ Disability law only entitles accommodation but does not stipulate what this should constitute.^{37,40,43} A recently published 5-year retrospective study of Massachusetts school nurses (a state with mandated stock epinephrine and reaction reporting) noted no association between “nut-free” schools and decrease in epinephrine use, although this was noted in schools with nut-free tables.⁴² No data exist regarding the use of, variation in instructions among, and efficacy of anaphylaxis management plans in schools.^{44,45} School anaphylaxis management operates on a “single student, single plan” and does

not use facility-level universal management for all students, an interesting choice because treatment for a reaction should not vary by student or allergen, per se.⁴⁶

Policy Recommendations Based on Environmental Risk Data

There are a few key considerations to make when creating policy pertaining to accommodations that aim to protect against the risk of peanut allergen exposure in the environment. It is well documented that families with food allergy often have poor quality of life, anxiety, mistrust, discomfort, and fear that caregivers of children and individuals with food allergy live with every day.^{6,47} There is empathy for this experience, and a desire to want to protect these individuals to the greatest extent possible as health care providers and maximize comfort in the environment. However, there is the reality of the medical evidence, which has (for years) noted very limited risk outside a few delineated situations and has provided objective data substantiating the concepts of allergen thresholds, environmental abatement, and lack of airborne peanut dust circulation.^{14–16} Thus, these policy arguments draw a forced conflict between medical necessity and provision of comfort. This often manifests as a 0-sum game, unfortunately.

Based on the environmental exposure data, there is no evidence to substantiate an airborne peanut exposure risk and very strong data to suggest that peanut on surfaces can be readily abated to lessen the risk of inadvertent mucus membrane contact from unnoticed hand contamination. Schoolwide or aircraft-wide bans would be viewed as medically unnecessary from a risk standpoint. Despite the absence of data that these types of policies decrease risk and that they might not be preferred as an option by all parents of children with food allergy, advocacy groups have argued in their favor. Instead, the focus should be on maximizing abatement strategies, because there is evidence they work and are minimally disruptive to other individuals.^{15,16} Localized bans (a buffer zone or classroom- or room-based restrictions) also are without any evidence of efficacy and are likely unnecessary from a medical standpoint. Again, abatement has proved efficacy and should be maximized. Aircraft buffer zones are problematic because they have been put into practice based on theory, without any testing for efficacy. The discussion in the Supplementary Data describes multiple potential flaws with buffer zones under the presumption that there actually is an airborne risk. The recent decision by the Canadian Transportation Agency to decrease the Air Canada buffer zone from 3 rows to 1 row is an intriguing compromise to the argument that recognizes the anxiety that a traveler with peanut allergy might face and provides them with some immediate proximity relief to enhance comfort that otherwise minimally alters normal cabin behavior given lack of evidence of an airborne exposure issue.³⁴ Individual classroom and room bans attempt to narrow the scope of restriction to only an isolated classroom or area where there might be shared

equipment among students, where food is served in the classroom, or in very young children in whom hand-to-mouth contact (with self and others) is more frequent and hand washing is less feasible. It is understandable that bans are likely a very preference-sensitive choice and of high value to many caregivers and advocates. Again, the difficulty comes in providing evidence-based approaches to provide protection to a potentially vulnerable segment and how to optimally achieve this.

Air travelers have precious few rights.^{48,49} A pilot can refuse boarding to anyone based on a medical condition that is deemed a risk to likely pose an in-flight emergency requiring diversion.^{50–52} Air travelers with allergy are granted rights against discrimination because of a medical condition. The airline cannot refuse to allow a traveler to purchase a ticket based on a medical condition, but accommodations when flying with peanut allergy are not guaranteed and are granted on a voluntary basis.^{48,49} The gray area is the declaration, at the time of boarding but after ticket purchase, of a potential life-threatening condition, and how the pilot, crew, and airline choose to handle that information. There is a fine line between discrimination and refusing passage to someone with a condition that might require extra effort to accommodate and the pilot assessing someone's flight risk when told the person has a life-threatening condition with little control of peanuts being on board beyond what the airline chooses to distribute. There are examples of how this is handled well by the traveler and/or the airline, and examples of how neither party handles this well. This is a process that is being worked out in real time by families and airlines. Continued dialogue by advocates from both sides is needed, but a firmer understanding of the delineation between medical necessity and provision of comfort must be a part of this process.

Schools have operated differently from airlines. Caregivers can, and very often do, enact Section 504 plans to provide accommodations for their child. This is their legal right, and there is a lot less gray area than exists with air travel. However, the issue is that the law does not provide explicit detailing of what a fair and appropriate accommodation is, allowing subjective interpretation.^{11,40,43} The 504 process is designed to engage multiple stakeholders to determine this, but the involvement of the stakeholders, the desires of the parties, and the execution of the final outcome can be variable. However, there is tremendous variation in physician knowledge of allergen risk, which could lead to an overstatement of risk (eg, that airborne risk exists), and lead to broader precaution than is necessary. The existing state and CDC voluntary guidelines do help to provide some recommendations as to how to determine what is fair and appropriate, but the degree of variation in their interpretation and the resulting outcome of the 504 plan are variable.^{53,54} Moreover, some solutions, such as schoolwide bans or isolated tables for eating, have been well intended but have resulted in unanticipated other consequences that make the situation worse (eg, social stigma, bullying, or poorer quality of life), or fail to influence the overall desired outcome. Thus, management of peanut allergy at school remains a work in progress.

Regardless of risk, there needs to remain a focus on treatment.⁵⁵ Allergic reactions are serious medical events that require immediate medical attention to ensure prompt, appropriate treatment in flight and in schools. Both place a heavy reliance on lay persons to recognize and manage a reaction.⁵⁶ The in-flight aircraft has unique constraints not faced by schools on the ground, in that they are isolated from resources and backup ordinarily available in a ground-based situation, and there is not always a provider on board who can treat a reaction.⁵⁰ Although a pilot can divert the aircraft for medical emergencies, diversion is an expensive and last-resort option that must be used very judiciously.^{50–52} Therefore, the onus is on passengers to be prepared to recognize and self-manage a reaction that might occur, and the crew should be able to help recognize, assist, and facilitate treatment.¹⁰ The same applies for lay persons

in a school, from teachers to administrators, given limited availability of on-site nursing in many schools. In both settings, there is evidence that epinephrine is underused as a treatment option.^{7–10} Policy as to when epinephrine should unequivocally be given as a first-line agent is clear. Epinephrine is indicated for any respiratory or cardiovascular symptoms or if there is evidence of involvement of at least 2 organ systems (eg, skin and gastrointestinal).⁵⁶ There is some controversy concerning whether epinephrine should be given for any symptom vs just severe symptoms or in the absence of symptoms if peanut has definitely been eaten.^{45,55} With a passenger self-carrying epinephrine, this will be administered at their discretion. However, approaches to this could differ at the school level, influenced by nationality (United States vs Canada), location, and availability of on-site nursing. For a school or in-flight reaction, it is very difficult to specify that all reactions should receive epinephrine, as has been advocated by some. Some providers err on the side of caution and recommend epinephrine use with diffuse hives, whereas other providers might advocate that with just skin symptoms that an antihistamine could be administered first and epinephrine should be administered second if symptoms escalate.^{57,58} Although it is common practice to instruct patients receiving epinephrine in the field to immediately seek emergency care and call an ambulance for transport,⁵⁸ fewer than 12% to 14% receiving epinephrine require an additional dose.^{59,60}

Conclusion

There is limited risk that nonoral exposure from ambient environmental levels will provoke a reaction in an individual with peanut allergy. Data exist that substantiate that peanut protein or dust does not aerosolize and pose an inhalational risk and that peanut-containing products on common surfaces can be readily abated to decrease unintended or unnoticed exposure from hand-to-mucus membrane contact. In addition, multiple data on allergen thresholds exist that denote trace residual levels likely pose no harm if ingested. Despite these data, restrictive policies that call for bans in schools and on aircraft continue to be pursued by many individuals with food allergy and advocates, which raises an uncomfortable clash between accommodations that lack any medical evidence of necessity and a desire to provide measures that comfort our patients. This is a 0-sum game, and better policy solutions are needed for individuals with peanut allergy who fly commercially and attend school. For the provider managing these patients, awareness and understanding of the data pertaining to risk are essential to help navigate such situations in which provider involvement is sought to help advise policy.

Supplementary Data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.anai.2018.03.011>.

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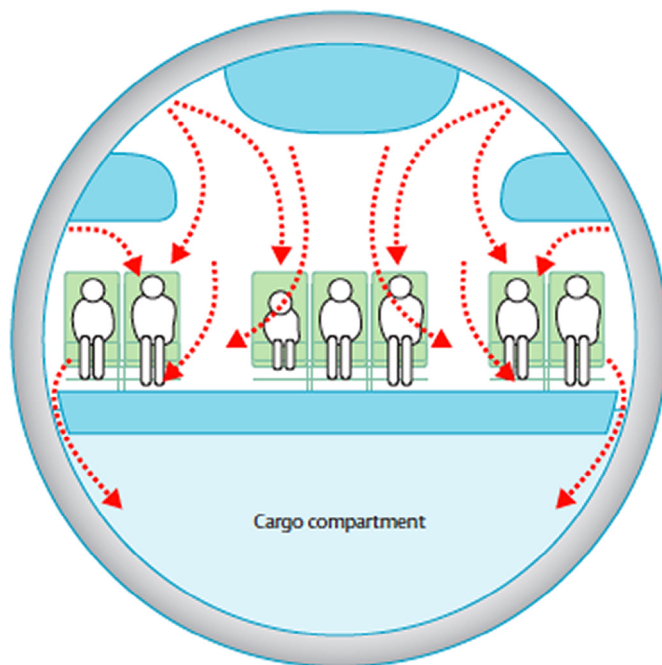
Supplementary Data

Quality and Flow of Air in a Pressurized Aircraft Cabin

Air in a typical cabin is pressurized to 6,000 to 8,000 feet of altitude, with the median cabin pressure at approximately 6,215 feet, which varies by airline and aircraft type.^{e1} At this altitude, passengers not acclimated to living at altitude can experience mild relative hypoxia as the fraction of inhaled oxygen decreases from 21% to 15% to 17%. The effect of the change from sea level on the average person is a lowering of the partial pressure of arterial oxygen from 75 to 100 mm Hg to approximately 60 mm Hg, resulting in an increased respiratory rate, lowered stroke volume, increased sympathetic nervous system tone, increase in a potentially hypercoagulable state, and increased risk of angina and abnormal heart rhythm.^{e2,e3} These effects occur on short and long haul flights.^{e1,e4} Because most individuals with food allergy are healthy children, without chronic obstructive pulmonary disorder or emphysema and assumed to have structurally normal hearts and no concern for coronary artery disease, the relative hypoxia is likely of no consequence. Asthma, common in individuals with food allergy, is generally not associated with baseline changes in ability to consume oxygen when an individual is not having an acute exacerbation.^{e5,e6} However, there are no data that can prove or disprove the effects during an allergic reaction at a lower oxygen content, including risk of acute coronary syndromes exacerbated from the decreased oxygen state.

Aircraft cabin pressurization results in air that contains less oxygen content relative to sea level air and is less humid. The air in the cabin is recirculated but mixed with fresh air that is drawn into the moving aircraft from the turbine intake of the engine, which is cooled and compressed before feeding into the ventilation system.^{e1,e4} From the ventilation system, the flow pattern is cross-sectional and bisects the width of the fuselage in a side-to-side pattern, with laminar (undisrupted, smooth) and downward directed flow from both sides of the aircraft as air enters above the seating row and over the seated passenger's head. Air exits the plane at the level of the foot, in vents placed on the fuselage sidewall. This allows for a deliberately cross-sectionalized air delivery pattern and limits longitudinal airflow from the front to the back of the cabin (eFig 1). Therefore, such flow limits the spread of airborne infectious particles. Depending on aircraft configuration, this cross-sectional flow can be symmetrical (twin aisle aircraft) or nonsymmetrical.^{e1,e4,e7}

Older aircraft (eg, Boeing 727, McDonald Douglas DC9, and some DC10 models) provided 100% freshly circulated air. However, newer-generation aircraft began to provide recirculated air in an attempt to increase fuel efficiency. There is no commercial Boeing 727, McDonald Douglas DC9, or DC10 aircraft currently in use by US or Canadian carriers. Approximately 50% of the air on nearly all aircraft models used in commercial flight is recirculated and mixed with fresh air. All recirculated cabin air is passed through a high-efficiency particulate air filter, the same grade that is used in hospitals, office buildings, and some homes, that removes 99.9% of particles at a lower limit of 0.3 μm . In an aircraft, the room air exchange rate is higher compared with a standard office building—15 to 20 cycles per hour compared with 12 (on average) for a building—and the ventilation capacity is greater, at 4.7 L/s (10 cubic feet/min).^{e1,e4,e7} These numbers will vary by aircraft type. There are no specific ventilation standards for a commercial aircraft, and carriers are not specifically required by any government authority to use a high-efficiency particulate air filter.^{e4,e7} There are limited literature and data to substantiate a heightened risk of exposure to airborne particles on an aircraft compared with exposure to the same particles in an office building. Interestingly, despite data that have shown that peanut does not aerosolize,^{e8,e9} Jones et al,^{e10} in a 1996 abstract presented at the American Academy of Allergy, Asthma, and Immunology meeting, reporting recovering small



eFigure 1. Model of air circulation in a passenger cabin.^{e7}

amounts of peanut allergen from the air filters of tested aircraft, although the mechanism of such particle deposition, and the timeline of such, is not known. Such an experiment has not been reproduced, and the association between that 1 case series and the risk of airborne peanut circulation has yet to be proved.

Human movement has been shown to affect the airflow distribution within a pressurized aircraft. Bodies moving in the aisle help create downward airflow behind a person's torso (similar to a boat wake), which augments the direction of the downward flow emanating from the ventilation system naturally. Faster walking speed will enhance such downward movement.^{e7,e11} This pattern was demonstrated quite elegantly in the wake of understanding the outbreak of severe acute respiratory disease among passengers on a flight from China in 2003.^{e11} In modeling studies of potential infectious disease dissemination on an aircraft with respect to disease carried through respiratory droplet secretions, human movement up and down the aisle (eg, mimicking normal crew activity) has been noted to have significant local effects that somewhat prevent side-to-side movement of respiratory particles. Such movement can increase longitudinal movement of particles, in that movement itself is believed to increase infection risk 1% to 2%, which when exploring potential routes of dissemination for severe acute respiratory disease on an aircraft was not deemed significant (eFig 2).^{e7,e11} This is the closest approximation of a model of how other potentially aerosolized agents, including food allergens, might behave under similar pressurized cabin conditions. Importantly, it should be carefully emphasized there are significant differences in the size and weight of the food particles (which are larger and heavier) compared with droplet-borne bacterial or viral particles in secretion that are propelled at velocity from human vectors. It is not clear how well such a model would mimic or approximate potential airborne allergen distribution.

Allergen Buffer Zones as a Specific Risk Mitigation Strategy

The theory of a buffer zone is to decrease the risk of airborne peanut (or other allergen) particles around a circumscribed area. Classically, this has been described as a 1- to 3-row (forward and

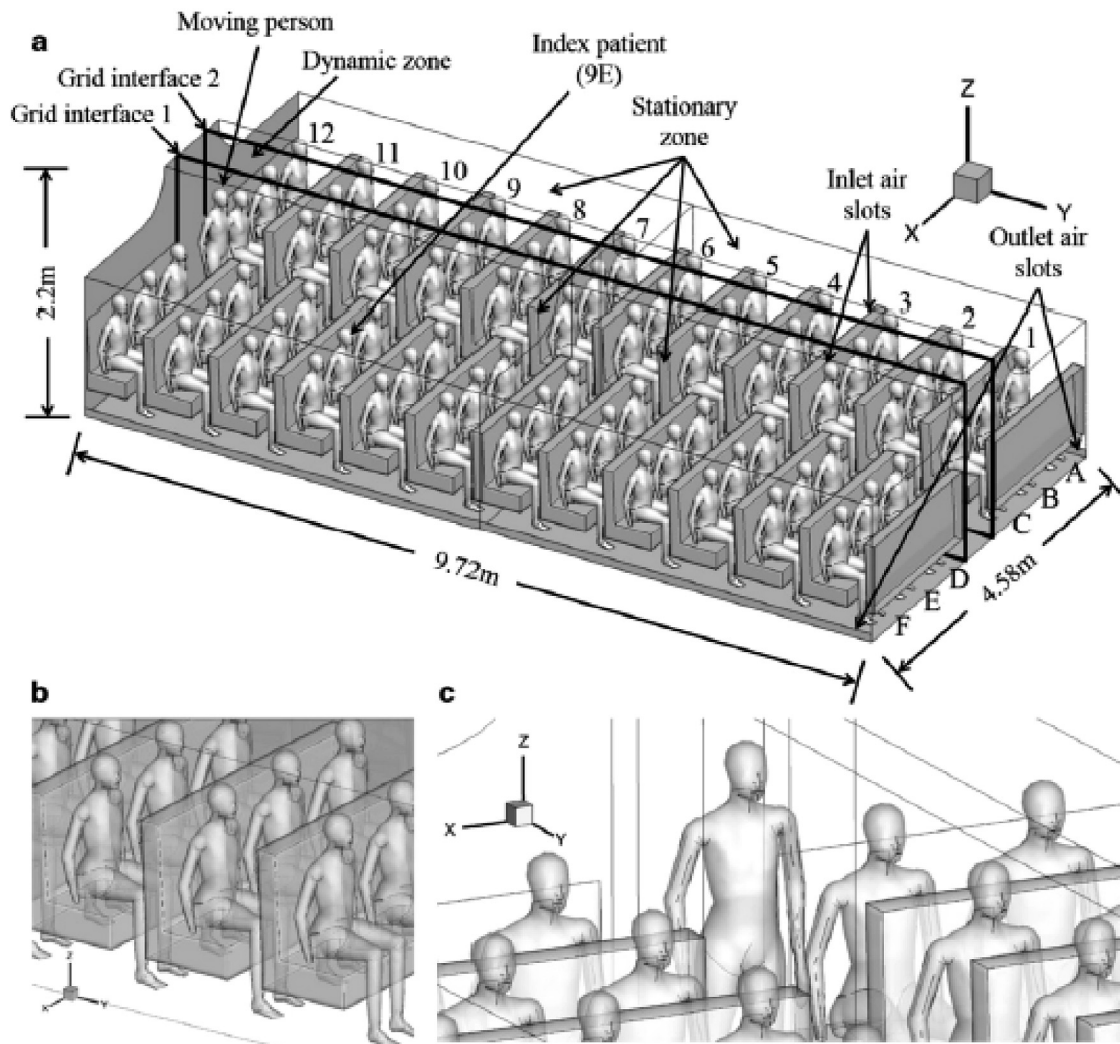


Figure 2. Passenger effects of airflow from routine cabin movement.^{e11}

back) exclusion zone spanning the sides and aisles of the plane around a specific row. It is unclear how the 1- to 3-row standard was chosen vs another row or distance configuration. Until the Air Canada decision, selected carriers used buffer zones sporadically as an accommodation. The Air Canada decision, based on a series of complaints to the Canadian Transportation Agency, created the following requirement^{e12}:

Peanut, tree nut, and sesame seed allergic passengers, upon request and with documentation of the allergy from a medical provider, would be granted a buffer zone of varying size around them where no peanut/tree nut containing snack or meal would be served or permitted (though trace contamination/cross-contact would not be able to be addressed), and passengers would be instructed not to consume such item. The airline was given authority to enforce compliance with this directive and could move a non-cooperative individual to another seat. Allergic passengers are expected to also take other precautions, such as providing their own allergen safe food, cleaning surfaces to mitigate risk, wearing a mask, and carrying self-injectable epinephrine.

Although initially a 3-row buffer zone, this was decreased to a same-row buffer zone in 2016 when the policy was revisited in a governmental inquiry.^{e13} The potential theoretical strengths of a

buffer zone are that it could isolate the vulnerable passenger and create a safe zone around that person for a specified distance, minimizing the likelihood of airborne or other form of exposure to the offending allergen. Moreover, as an alternative to creating a flight entirely free of peanut, tree nut, or sesame seed, it provides a compromise that could promote some protection of the vulnerable passenger while minimizing disruption to other passengers. It also would limit the area in which cabin crew would have to enforce a potentially unpopular restrictive policy, which could prove a difficult task.

There are many potential weaknesses to a buffer zone policy, foremost being the lack of data that peanut, tree nut, or sesame seed allergen can become airborne.^{e8,e9} Buffer zones remain a scientifically untested accommodation.^{e13} Conceptually there are multiple commonsense and scientific challenges that could be raised, suggesting this strategy is most likely a measure of comfort and psychological accommodation rather than a physiologic one. There has been no study demonstrating that a buffer zone has clinical efficacy or whether other abatement techniques (eg, not distributing allergen-containing products, cleaning of personal areas, or multiple permutations of several strategies, etc) would have comparative efficacy.^{e14} There has been no study to establish an optimal row distance for potential separation of a passenger with allergy from the trigger allergen. Because airflow occurs on a cross-sectional arc and

not longitudinally within the cabin, and flows from the overhead above the level of the passenger's head outward to the middle of the aisle and then downward toward the feet (eFig 1), it is unclear what the extent of possible exposure could be, if any.^{e7}

Assuming a buffer zone is created, protected passengers would more than likely still have to walk through areas of the airplane where the allergen is consumed to use the lavatory and to enplane and deplane, which could defeat the purpose of partial zone isolation if there is any wake distribution effect.^{e11} This scenario would more than likely occur on every flight. It is unknown whether such exposure while walking through an “unbuffered zone” has provoked a reaction, because buffer zones have not been studied, and there could be placebo effects from provision of this as an accommodation. Moreover, to establish the maximal effectiveness of a buffer zone, it would be presumed that the same static set of rows would need to be included in the buffer zone on every flight for that aircraft on the same day to maximize a “sterile” local environment over the course of a day's worth of flights and cabin cleaning cycles. It is unclear if this is actually done or if the zoned-off seats move to where the passenger wanting the accommodation is seated. Given the lack of study of this concept, it is unclear whether there is any effect of moving the buffer zone to accommodate where a passenger has been selected to sit on each given flight where this is used as opposed to seating the passenger in a static area on the aircraft within the buffer zone. This facet in and of itself is absolutely critical to the efficacy of the concept. Furthermore, there has been no study to determine what the most optimal place on an aircraft would be to place a buffer zone that is more or less susceptible to potential airborne distribution, and if this varies by type of aircraft involved.

In what could likely be the greatest threat to the individual with allergy, the effect of differential cabin cleaning of potentially contaminated surfaces is unknown despite establishing a buffer zone. There could be an additive or a detrimental effect between the level of surface cleaning and other accommodation. Hypothetically, a passenger with allergy walking through or congregating in an “unbuffered” area could come into contact with an unwashed surface that could contain settled allergen particles (eg, a lavatory door handle, an armrest or seatback, or other surface). If this occurs and that passenger does not then wash his or her hands before mucosal contact, there would be some likelihood of inadvertent ingestion of the allergen and potential reaction that would have little to do with the efficacy of the buffer zone.

Thus, it is hard to make an accurate determination of the medical necessity, conceptual feasibility, and technical efficacy of a buffer zone. It would be strongly recommended that the requirement be better tested for efficacy and, if proved efficacious, that it be tested

for optimization in terms of where on a plane it would work best, how many seats or rows should be involved, and what other strategies might help optimize the buffer zone's efficacy. This process should include a parallel investigation of customer service satisfaction specifically regarding this issue from passengers with and without allergy and the flight crew to understand the impact from various stakeholders and integrate any available data to substantiate that the rate of reported reactions underwent positive change. However, given the dynamics of cabin airflow, the lack of evidence that peanut aerosolizes, and the evidence that surface wiping as abatement is highly effective, it would be strongly encouraged that the program be re-evaluated for evidence of necessity, which given current evidence, would be highly questionable. Moreover, if the buffer zone does not provide any level of protection, the requirement should be abandoned to avoid any misleading sense of security. This would represent a worse-case scenario to all parties—an accommodation that provides no protection.

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