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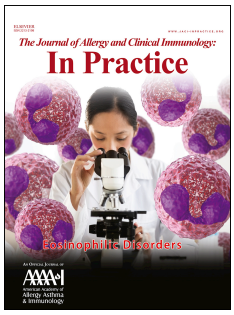

First Dose mRNA COVID-19 Vaccine Allergic Reactions: Limited Role for Excipient Skin Testing

Anna R. Wolfson, MD, Lacey B. Robinson, MD, MPH, Lily Li, MD, Aubree E. McMahon, BA, Amelia S. Cogan, MPH, Xiaoqing Fu, MS, Paige Wickner, MD, MPH, Upeka Samarakoon, MS, PhD, Rebecca R. Saff, MD, PhD, Kimberly G. Blumenthal, MD, MSc, Aleena Banerji, MD

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Anna R. Wolfson, MD[1,2]

Lacey B. Robinson, MD, MPH[1,2]

Lily Li, MD[1,3]

Aubree E. McMahon, BA[2]

Amelia S. Cogan, MPH[2]

Xiaoqing Fu, MS[2]

Paige Wickner, MD, MPH[1,3]

Upeka Samarakoon, MS, PhD[2]

Rebecca R. Saff, MD, PhD[1,2]

*Kimberly G. Blumenthal, MD, MSc[1,2,4]

*Aleena Banerji, MD[1,2]

[1] Harvard Medical School, Boston, MA

[2] Division of Rheumatology, Allergy, and Immunology, Department of Medicine, Massachusetts General Hospital, Boston, MA

[3] Division of Allergy and Clinical Immunology, Brigham and Women's Hospital, Boston, MA

[4] Edward P. Lawrence Center for Quality and Safety, Massachusetts General Hospital, Boston, MA

*Co-senior authors

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Corresponding Author: Anna R. Wolfson, MD, Massachusetts General Hospital, Allergy and Immunology, Cox 201, 55 Fruit Street, Boston, MA 02114, p-(617) 726-3850, f- (617) 724-0239, awolfson@mgh.harvard.edu; Twitter: @AnnaWolfsonMD

E-mail addresses:

Anna R. Wolfson awolfson@mgh.harvard.edu

Lacey B. Robinson lbrobinson@mgh.harvard.edu

Lily Li lli39@bwh.harvard.edu

Aubree E. McMahon aemcmahon@mgh.harvard.edu

Amelia S. Cogan ascogan@mgh.harvard.edu

Xiaoqing Fu xfu2@mgh.harvard.edu

Paige Wickner pwickner@bwh.harvard.edu

Upeka Samarakoon ssamarakoon@mgh.harvard.edu

Rebecca R. Saff rsaff@mgh.harvard.edu

Kimberly G. Blumenthal kblumenthal@mgh.harvard.edu

Aleena Banerji abanerji@mgh.harvard.edu

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ARW, LBR, LL, XF, PW, US, AEM, ASC, RRS, KGB, AB have nothing to disclose relevant to this paper.

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Abstract:

Background: CDC states that a severe or immediate allergic reaction to the first dose of an mRNA COVID-19 vaccine is a contraindication for the second dose.

Objective: To assess outcomes associated with excipient skin testing after a reported allergic reaction to mRNA COVID-19 vaccine dose one.

Methods: We identified a consecutive sample of patients with reported allergic reactions after the first dose of mRNA COVID-19 vaccine who underwent allergy assessment with skin testing to polyethylene glycol (PEG) and, if appropriate, polysorbate 80. Skin testing results in conjunction with clinical phenotyping of the first dose mRNA COVID-19 vaccine reaction guided second dose vaccination recommendation. Second dose mRNA COVID-19 vaccine reactions were assessed.

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Results: 80 patients with reported first dose mRNA COVID-19 vaccine allergic reactions (n=65, 81% immediate onset) underwent excipient skin testing. 14 (18%) had positive skin tests to PEG (n=5) and/or polysorbate 80 (n=12). Skin testing result did not impact tolerance of second dose in patients with immediate or delayed reactions. Of 70 (88%) patients who received their second mRNA COVID-19 vaccine dose, 62 (89%) had either no reaction or a mild reaction managed with antihistamines, but two patients required epinephrine. Three patients with positive PEG-3350 intradermal (methylprednisolone) testing tolerated second dose mRNA COVID-19 vaccination. Refresh Tears caused non-specific irritation.

Conclusion: Most individuals with a reported allergic reaction to dose one of the mRNA COVID-19 vaccines, regardless of skin test result, received the second dose safely. More data are needed on the value of skin prick testing to PEG (Miralax) in evaluating patients with mRNA COVID-19 vaccine anaphylaxis. Refresh Tears should not be used for skin testing.

Highlights Box:

1. What is already known about this topic? An expert-informed risk stratification protocol was recommended to guide clinical care after mRNA COVID-19 vaccine reactions, however, at the time there was no supportive evidence available.

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2. What does this article add to our knowledge? Most individuals after first dose mRNA COVID-19 vaccine reactions, regardless of excipient skin testing result, were able to safely receive the second mRNA COVID-19 vaccine dose. Refresh Tears were irritating and should not be used for skin testing to polysorbate 80.

3. How does this study impact current management guidelines? More data on the value of skin prick testing to PEG (Miralax) in evaluating patients with mRNA COVID vaccine anaphylaxis is needed and the positive predictive value remains unknown. Most patients may be able to proceed to second vaccination without skin testing.

Key words: *COVID-19 vaccine, drug allergy, vaccine allergy, COVID-19, PEG allergy, skin testing, Polysorbate allergy, excipient allergy, anaphylaxis.*

Abbreviations:

Coronavirus Disease-2019 (COVID-2019)
Emergency Use Authorization (EUA)
Food and Drug Administration (FDA)
Centers for Disease Control and Prevention (CDC)
Polyethylene glycol (PEG)
Mass General Brigham (MGB)
E-consult (electronic consult)
Massachusetts General Hospital (MGH)
Brigham and Women's Hospital (BWH)
REDCap (Research Electronic Data Capture)
Electronic Health Record (EHR)
Standard Deviation (SD)
Interquartile Range (IQR)
Negative Predictive Value (NPV)

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Intradermal (ID)

Introduction:

One year after the World Health Organization declared COVID-19 (Coronavirus Disease-2019) a pandemic, greater than 138 million people have been infected and every country in the world has been impacted.[1] It was with excitement and hope that millions of Americans welcomed the approval of two novel COVID-19 mRNA vaccines in December 2020. However, almost immediately following Emergency Use Authorization (EUA)[2] by the Food and Drug Administration (FDA) of the Pfizer-BioNTech COVID-19 mRNA vaccine, initial reports of anaphylaxis and allergic reactions began. When the Moderna COVID-19 mRNA vaccine was approved soon thereafter, similar reports emerged.[3] The reports of anaphylaxis prompted the Centers for Disease Control and Prevention (CDC) to develop formal guidance for administration of the Pfizer-BioNTech and the Moderna mRNA COVID-19 vaccines, stating that patients with a history of anaphylaxis to vaccine components should not receive mRNA COVID-19 vaccines,[4] and patients with a history of an immediate allergic reaction to the first dose of mRNA COVID-19 vaccine should not receive the second dose.[5]

In December, 2020, national anaphylaxis rates were reported by the CDC initially to be as high as 11.1 per million doses of the Pfizer-BioNTech COVID-19 vaccine,[6] but, by January, 2021, CDC estimates reported an anaphylaxis incidence of 2.5 to 4.7 per million doses of the Moderna and Pfizer-BioNTech COVID-19 vaccines, respectively.[7] In the first prospective real world cohort of 60,000 employees vaccinated at a large healthcare system (Mass General Brigham, [MGB]), an incidence of 2.5 cases of anaphylaxis per 10,000 mRNA COVID-19 vaccines administered was reported.[8] The cause of allergic reactions to mRNA COVID-19 vaccines

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remains unknown, but the excipient PEG-2000, present in the mRNA COVID-19 vaccines,[9] has been an important focus of investigation with recent limited supportive evidence.[10] Furthermore, the utility of skin testing to PEG and polysorbate 80 was unclear but experts suspected excipient skin testing to have a high positive predictive value and a low negative predictive value.[11,12] At the time of publication, there are three COVID-19 vaccines which have received FDA EUA: two contain PEG-2000 (Pfizer-BioNTech and Moderna mRNA COVID-19 vaccines) and one contains polysorbate 80 (Janssen adenovirus vector vaccine). Thus, it is important to understand whether there is a relationship between allergy to these excipients and allergic reactions to the COVID-19 vaccines.[9]

Our risk stratification algorithm[13] uses clinical history with skin testing to PEG and/or polysorbate to evaluate higher risk individuals who report a history of an immediate allergic reaction to a first dose of mRNA COVID-19 vaccine. Herein, we report the outcomes of individuals referred for reported allergic reactions to a first dose of mRNA COVID-19 vaccine that completed skin testing and followed our initial published skin testing guidance.[13] We review patient and reaction characteristics with skin testing findings along with second dose vaccine outcomes that motivate an updated approach to individuals who present following a reported allergic reaction to the first dose of mRNA COVID-19 vaccine.

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Methods:
This cohort included consecutive patients referred for an in-person allergy/immunology excipient skin testing visit which occurred at MGB between January 6 and March 3, 2021 after a first dose mRNA COVID-19 vaccine reaction. In-person visits occurred after initial allergy/immunology telemedicine visits with clinical phenotyping and risk stratification. All included patients received their first mRNA vaccine dose at an MGB vaccination clinic with second doses scheduled at the vaccination clinics associated with the MGB academic medical centers: Massachusetts General Hospital (MGH) or Brigham and Women's Hospital (BWH).

We recommended excipient skin testing to all patients who reported symptoms concerning for an IgE-mediated allergy within 4 hours of vaccination. Patients with symptoms consistent with an allergic reaction which was delayed (occurring more than 4 hours after vaccination but before day 3 post vaccination) may also have proceeded to excipient skin testing, especially if the symptoms were more severe or patient preference using shared decision-making. For patients who reported symptoms which were potentially IgE-mediated but subjective (e.g., globus or itch without rash), the decision to proceed to skin testing was also based on shared decision-making considering patient preferences. Interested and eligible patients were referred for an in-person excipient skin testing appointment at either MGH or BWH. Approximately 14% of patients with first dose mRNA COVID-19 vaccine reactions were referred for in-person excipient skin testing using our algorithm.[13]

At MGH, PEG skin testing was performed using Miralax, a laxative containing PEG-3350, epicutaneous and methylprednisolone acetate (containing PEG-3350 only[13]) intradermally (Table E1).[13] If methylprednisolone acetate was positive, methylprednisolone sodium succinate

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was used as a control to exclude methylprednisolone as the cause of allergy. At MGH, for individuals with first dose mRNA COVID-19 vaccine reactions, skin testing to polysorbate 80 (using triamcinolone acetonide[14]) was performed if PEG skin testing was positive to help guide future COVID-19 vaccination or if the patient reported a history of a reaction to another vaccine containing polysorbate 80. At BWH, PEG (Miralax and methylprednisolone acetate containing PEG 3350 only) skin testing was similar although polysorbate 80 testing used Refresh Tears and was performed regardless of PEG skin testing result. All sites required adequate positive (histamine) and negative (saline) controls for epicutaneous and intradermal tests. Patients with negative skin testing were advised to proceed to second dose mRNA COVID-19 vaccination. Shared decision-making was used for patients with positive skin test to PEG and/or polysorbate 80.

We used excipient skin testing alone -- without mRNA COVID-19 vaccine skin testing --which has since been described,[15,16] as we did not have access at the time to mRNA COVID-19 vaccine for skin testing purposes and the mRNA COVID-19 vaccines were the first vaccines of their kind. It was not apparent that any prior vaccine guidance[17] could be accurately applied to these vaccines and there was initial concern that dilution could degrade mRNA so it could not be used as a skin testing product nor as a graded challenge.[18]

Due to concern which arose during this study for irritant skin testing reactions to Refresh Tears, control skin tests were performed on 25 non-allergic subjects who reported clinical tolerance to polysorbate 80.

Data Collection and Definitions

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Clinical data were gathered from manual electronic health record (EHR) review by trained research assistants (AEM, ASC) with allergist oversight (ARW, LBR, LL). Structured MGB allergist note templates used during clinic visits facilitated accurate demographic, past medical and allergy history, skin test results, and outcomes. Study data were collected and managed using REDCap (Research Electronic Data Capture) tools.[19,20]

Immediate allergic reactions were defined as occurring within the first four hours, and delayed allergic reactions occurred anytime thereafter. Reaction details were categorized by organ system of involvement. Cutaneous included itching, rash, hives, flushing and swelling. Cardiovascular included hypotension and tachycardia. Lower respiratory included cough, wheezing, chest tightness or shortness of breath. Upper airway included globus, hoarseness, and throat swelling. Gastrointestinal included abdominal pain, nausea, vomiting, and diarrhea.

For patients who received their second mRNA COVID-19 vaccination, we assessed tolerance of the vaccine using three days of electronically-disseminated symptoms surveys. If a patient did not respond to all three days of the survey, or if they reported allergic symptoms on the survey, they were contacted by phone or e-mail message by an allergist/immunologist (ARW) to assess tolerance of the second dose of mRNA COVID-19 vaccine. Individuals who received the Janssen vaccine in lieu of second mRNA COVID-19 vaccines were considered to have not received their second mRNA COVID-19 vaccine dose but to have been completely vaccinated.

The index allergic reaction to the first mRNA COVID-19 vaccine and, when relevant, the allergic reaction to the second mRNA COVID-19 vaccine, were graded using Ring and Messmer

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criteria[21] (Table E2) by two allergists independently; in the case of discordant grading, a third allergist was used to determine the final grade (ARW, LBR, LL). We defined second dose tolerance as either no allergic reaction or a grade 0 reaction with mild subjective symptoms that did not require treatment.

This study was approved by the MGB Partners Institutional Review Board, protocol number 2020P004068.

Data Analysis

Data are presented as counts with frequencies for categorical data and means with standard deviation (SD) or medians with interquartile ranges (IQR) for continuous variables, as indicated. All analyses were performed in SAS (version 9.4, Cary, NC, USA). We calculated the negative predictive value (NPV) for PEG skin testing result and having a reaction with mRNA COVID-19 vaccine dose two for the entire sample and considering only patients with immediate reactions.

Results:

There were 80 patients who underwent excipient skin testing at MGB after a reported allergic reaction to the first dose of mRNA COVID-19 vaccine (**Table 1**). 18 (23%) reported a reaction to Pfizer-BioNTech and 62 (77%) to the Moderna COVID-19 mRNA vaccine. 38,933 (60%) Moderna and 25,906 (40%) Pfizer-BioNTech vaccines were administered at MGB during the study period and a total of 576 allergy/immunology telehealth visits were performed for COVID-19 vaccine reactions.

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Patient Characteristics

Patients were predominantly female (89%) and white (78%) with mean age 40.9 ±13.6 years. Past medical history included a history of non-anaphylactic IgE mediated food allergy (n=29, 36%), asthma (n=25, 31%), anaphylaxis to medications, foods, venom or latex (n=22, 28%), allergic rhinitis (n=20, 25%), polysorbate allergy (n=5, 6%), atopic dermatitis (n=4, 5%), and PEG allergy (n=2, 3%) (**Table 1**).

Reaction Characteristics

There were 65 (81%) patients reporting an immediate reaction; 40 (62%) occurred within the first 30 minutes with the median onset of symptoms within 10 [IQR: 5,15] minutes. The following symptoms were reported: cutaneous (n=51, 78%), lower respiratory (n=14, 22%), cardiovascular (n=10, 15%), and subjective symptoms including lightheadedness and tingling (n=21, 32%). 47 (72%) patients received antihistamine treatment and 6 (9%) received epinephrine; 18 (28%) were treated in the emergency department. Of the 65 immediate allergic reactions, 21 (32%) were grade 0, 33 (51%) were grade 1, and 11 (17%) were grade 2. All individuals recovered from their reaction without long-term sequalae.

There were 15 (19%) patients who experienced delayed allergic reactions; 1 (7%) patient received Pfizer and 14 (93%) received Moderna (**Table 1**). Of these, 11 (73%) had symptoms within the first 24 hours after receiving the vaccine and 4 (27%) had symptoms starting 24 hours or more after the vaccine was administered. The delayed symptoms were most frequently cutaneous (n=14, 93%), other symptoms as in Table 1. One patient was treated in the emergency department.

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Skin Testing Results

Of the 80 patients who underwent excipient skin testing, 33 had testing to PEG only, 47 had testing to PEG and polysorbate 80 (n=41 to Refresh Tears; n=6 to triamcinolone acetonide). In all, 14 (18%) had a positive skin test result (**Table 2**): PEG only (n=2), PEG and polysorbate 80 (n=3), and polysorbate 80 only (n=9, **Figure 1a**). All polysorbate 80 positive individuals were positive on skin testing to Refresh Tears (n=12), which was found to be an irritant in 13 of 25 (52%) non-allergic controls (**Table E3**). Among the 65 patients presenting with an immediate allergic reaction, 8 (12%) had positive skin tests: PEG (n= 2), PEG and polysorbate 80 (n=2), and polysorbate 80 (n=4, **Figure 1b**). These patients with PEG positive skin tests were positive on intradermal testing to methylprednisolone acetate 4 mg/mL (n=1), methylprednisolone acetate 0.4 mg/mL (n=2) and to Miralax 1:100 epicutaneous (n=1). Among the 15 patients with a delayed allergic reaction, 6 (40%) had positive skin testing: 5 (33%) to polysorbate 80 and 1 (7%) to both PEG (intradermal testing to methylprednisolone acetate 0.4mg/mL) and polysorbate 80 (**Figure 1c**). No allergic or adverse events occurred during any skin testing procedures.

Tolerance of the Second Dose of the Vaccine Overall

Of the 80 patients who underwent excipient skin testing, 70 (88%) received a second dose of the same mRNA COVID-19 vaccine and 52 (74%) tolerated the second dose vaccine without a reaction (**Figure 1a**). The NPV of a negative skin test to PEG predicted a 75% likelihood of tolerating the second dose of the vaccine

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Among the 65 patients who reported an immediate allergic reaction to the first dose of mRNA COVID-19 vaccine, 58 (89%) received their second dose of the vaccine, and 43 (74%) tolerated their second dose without reaction (**Figure 1b**); 2 (3%) received epinephrine treatment for their second dose reaction. Among the 65 patients who reported an immediate reaction to the first dose of mRNA COVID-19 vaccine, the NPV of a negative skin test to PEG was 75%.

Tolerance of the Second Dose of the Vaccine Among Skin Test Negative Patients

Overall, 66 (83%) patients were skin test negative and 60 (91%) of these patients went on to receive their second dose of the vaccine, 45 (75%), ultimately had the second dose of the vaccine without recurrent symptoms. Among the 65 patients who reported an immediate allergic reaction to the first dose of mRNA COVID vaccine, 57 (88%) were skin test negative, 52 (80%) received their second dose of the vaccine, and 39 (75%) had no symptoms with the second dose. There were 13 (25%) patients who were skin test negative but reacted to the second dose of the vaccine, and their most common symptoms were cutaneous (n=11) but 4 (31%) patients were seen in the Emergency Department and 2 (15%) received epinephrine (**Table 3**).

Among the 15 individuals who reported a delayed reaction after the first dose of mRNA COVID-19 vaccine, 9 (60%) were skin test negative and 8 (89%) received their second vaccine dose; 6 of 8 (75%) tolerated the second dose without reaction. Two patients who were skin test negative but reacted to the second dose of the vaccine reported the following symptoms: one had mild swelling of throat, tongue, and eyes, pruritus without rash on face and chest, no treatment was sought; one had pruritus and erythema of arms, with pruritus of lips and neck, treated with antihistamines.

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Tolerance of the Second Dose of the Vaccine Among Skin Test Positive Patients

Among the 8 (12%) patients who reported a history of an immediate allergic reaction and a positive skin test: 4 (67%) tolerated the vaccine (skin test positive to: polysorbate 80/Refresh Tears [n=2], PEG/methylprednisolone acetate ID [n=1], PEG/ methylprednisolone acetate ID and polysorbate 80/Refresh Tears [n=1]); 2 (33%) had mild allergic reactions; 2 (25%) after shared decision-making, opted to not receive the second mRNA COVID-19 vaccine dose (both skin test positive to PEG, 1 patient was skin prick positive to Miralax and 1 patient opted to instead receive the Janssen vaccine) (**Table 2**). The two patients with dose two reactions were positive to Refresh Tears and both had mild symptoms. The two patients who had PEG skin test positive but tolerated the vaccine were positive to methylprednisolone acetate on intradermal testing; the only patient with a positive to Miralax on epicutaneous testing had experienced anaphylaxis requiring epinephrine after the first dose of the vaccine and was not re-challenged.

Among the 15 patients who reported a delayed allergic reaction to the first dose of mRNA COVID-19 vaccine, there were 6 with a positive skin test, 3 tolerated the vaccine (skin test positive to: polysorbate 80/Refresh Tears [n=2], PEG/methylprednisolone acetate ID and polysorbate 80/Refresh Tears [n=1]); 1 had a mild allergic reaction; and 2 have not received dose two (skin test positive to polysorbate 80/Refresh Tears). The patient who had a dose two reaction was positive to polysorbate 80/Refresh Tears and experienced subjective symptoms (**Table 2**). The patient with positive skin testing to PEG was positive only on intradermal testing to methylprednisolone acetate.

Discussion:

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Among 80 individuals referred for excipient skin testing after a reported allergic reaction to the first dose of mRNA COVID-19 vaccine the vast majority of patients received the second mRNA COVID-19 vaccine dose safely irrespective of skin test results. Two patients who were treated with epinephrine after their second dose had been treated with epinephrine after their first dose as well. However, three additional patients that received epinephrine after their first dose tolerated their second vaccine, therefore, while there are no clear risk factors, this is an important issue for physicians to discuss with patients that were treated with epinephrine after the first dose of the mRNA COVID-19 vaccine. Notably, it is possible that epinephrine was not necessary in these cases. Overall, excipient skin testing did not add value to the clinical risk assessment in those reporting first dose mRNA COVID-19 vaccine reactions even when applied to a highly selected group that represented just 14% of mRNA COVID-19 vaccine reactions evaluated by allergy/immunology in this period overall. However, PEG skin prick testing may be useful in guiding second dose vaccination in individuals with anaphylaxis to the first dose of the mRNA COVID-19 vaccine although its positive predictive value remains unknown.

Based on our data and experience to date, we propose an updated risk stratification algorithm after reported first dose mRNA COVID-19 vaccine allergic reactions (**Figure 2**). First, the clinical history still remains the most important aspect in the allergist evaluation; using shared decision-making, most individuals with reactions to the first dose of an mRNA COVID-19 vaccine can proceed safely with second dose. [22-24] Second, excipient skin testing is favored over vaccine skin testing,[15,16] as vaccine is largely inaccessible to most allergists and the mRNA vaccines are still under EUA. Third, in terms of premedication, although some patients in the cohort were pre-treated with antihistamines or steroids, this study was not designed to determine

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an optimal premedication regimen. The authors have used premedication with non-sedating antihistamines for patients with mild symptoms such as delayed urticaria, but try to restrict use of glucocorticoids that may an unfavorable immunologic effect.[25] Fourth, in our experience to date, PEG skin testing was of limited utility (n=5 with positive skin tests), and should only be considered in specific cases, e.g. patients with convincing history of anaphylaxis to mRNA COVID-19 vaccine or recently to oral PEG-containing medications. Lastly, methylprednisolone acetate or PEG intradermal skin testing did not provide additional information to guide safety of second dose mRNA COVID-19 vaccination as patients (n=3) with positive skin testing to this tolerated the vaccine, in our experience. We thus suggest that, when PEG excipient testing is warranted, epicutaneous testing to Miralax (PEG3350) alone is adequate.[10,11,12] In our experience, consistent with rare true cases of anaphylaxis to the COVID-19 mRNA vaccines, Miralax skin testing was positive in one patient with symptoms consistent with anaphylaxis. This patient did not receive a second dose of COVID-19 vaccine so the positive predictive value of Miralax skin testing remains unknown.[10,26] (**Figure E1**).

The cause of mRNA COVID-19 vaccine allergic reactions remains unclear and may be multifactorial, but one case report linked PEG as a possible allergen[10] and an improved understanding of the role for excipient skin testing to PEG in individuals with a history of anaphylaxis to mRNA COVID-19 vaccines is still needed. While we were able to calculate the NPV for PEG skin testing and tolerance with dose two, we were unable to calculate sensitivity, specificity, and/or positive predictive value. There were two patients who reported histories of being allergic to PEG (reported after their first dose mRNA COVID-19 vaccine reaction). Interestingly, both were PEG skin test negative and 1 patient tolerated dose two without symptoms and the other developed subjective globus sensation after dose two treated with

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antihistamines only. Three patients positive on intradermal PEG (methylprednisolone acetate) skin testing tolerated their second mRNA COVID-19 vaccine dose without any reactions. Additionally, in our experience, a portion of skin test negative patients had reactions to their mRNA COVID-19 vaccine second dose. While the majority had easily treatable reactions and are now fully vaccinated, importantly, two were treated with epinephrine and four were treated in the Emergency Department, emphasizing the important role for an allergist in the care of these patients. Thus, since skin test positive patients tolerated the second dose of the vaccine and skin test negative patients had reactions, skin testing did not add additional information regarding the tolerance of the second mRNA COVID-19 vaccine dose.

Due to the high rate of skin test positivity to Refresh Tears, which was used as a source of polysorbate 80 in the BWH study population, we tested a new control group (Table E3). Approximately half of the non-allergic controls had positive skin test results suggesting that Refresh Tears is likely causing an irritant, or false positive, skin test reaction. These findings prompted us to modify our initial algorithmic approach and also to contact all MGB patients with positive skin tests to Refresh Tears to modify our initial advice and encourage mRNA COVID-19 vaccination. None of the patients with positive skin tests to Refresh Tears that received the second dose of the mRNA COVID-19 vaccine developed an allergic reaction, but three patients had subjective symptoms and were treated with antihistamines only.

Vaccine hesitancy is an important issue that may be exacerbated by adverse and/or allergic symptoms after the first dose of the mRNA COVID-19 vaccine, and we are eager to reassure our patients regarding the vaccine's safety in order to encourage vaccination.[27] In our cohort of individuals referred for skin testing, 10 out of 80 have not received their second dose of mRNA

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COVID-19 vaccine, although only 2 were advised by our group to not receive mRNA COVID-19 vaccine (a third patient received Janssen vaccine). The reasons for incomplete vaccination are not clear, but may include vaccine administration logistics, unclear benefit of second dose vaccination, and/or concern about having a recurrent allergic or adverse reaction.[28] The allergist may not be able to address all these barriers, but the allergist can acknowledge them,[29] and, based on these data, provide reassurance around receiving the second dose if the clinical history is low risk.[12,13,16,30] The allergist also has an important role in helping to correctly recognize and treat allergic reactions, so allergist-observed second dose vaccinations may help reassure our patients.

Recently, the CDC added guidance allowing Janssen COVID-19 vaccine at least 28 days after an allergic reaction to a first dose of mRNA COVID vaccine, broadening our patients' options.[5] The Janssen COVID-19 vaccine contains the excipient polysorbate 80 but not PEG and therefore could be administered without skin testing to PEG in patients concerned about PEG allergy. Janssen COVID-19 vaccine could also be considered in an individual with a history of PEG allergy or PEG skin test positivity but a negative polysorbate 80 skin test or tolerance of vaccine with polysorbate 80 (**Figure 2**). Reassuringly, to date, the rate of allergic reactions to the Janssen vaccine appears exceedingly low.[31] One patient in our cohort who had reported an immediate allergic reaction to Moderna, then had positive skin testing to methylprednisolone acetate and Refresh Tears has subsequently tolerated the Janssen vaccine. This is an important option for our high-risk patients with possible PEG allergy.

The limitations of our study include generalizability as our study population was a referred population consisting of MGB patients evaluated by a specialist. The majority of our patients

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were white females, which was likely a reflection of the overrepresentation of white females in the healthcare worker population in the Boston area. The demographics may limit generalizability across demographics although these demographics closely match those reported nationally.[3,6,7] These data are subject to information bias as we do not know why some individuals chose not to receive their second dose of the vaccine, even when the allergist advised that it was safe to proceed. Given that proceeding to a second mRNA COVDI-19 vaccine dose was not at random, we acknowledge that there is a bias in calculation of an NPV. However, while NPV could be calculated given that only 9% of skin test negative patients did not receive dose two, we were unable to calculate PPV given that 40% of skin test positive patients did not receive dose two and sample size was just 5. Another limitation is that symptoms were self-reported. Although we intended to only use excipient skin testing in high risk individuals, some individuals reported minor and subjective symptoms (e.g. itch, globus, diziness); including these symptoms in our analysis may have made it more difficult to ascertain the association of excipient skin testing with true mRNA COVID-19 vaccine allergy. However, the inclusion of these patients was due to patient preference and shared decision-making.

Overall, our initially published risk stratification protocol[13] allowed safe second dose mRNA COVID-19 vaccination for the vast majority of individuals despite a reported first dose allergic reaction. We have since learned that excipient skin testing may be of little utility in the assessment of these reactions, particularly in individuals without anaphylaxis. More data are needed to identify whether PEG skin prick testing after a reaction clinically consistent with severe anaphylaxis to mRNA COVID vaccine is predictive of a reaction with subsequent mRNA COVID-19 vaccine. Additional studies focusing on specific reaction phenotypes, notably anaphylaxis, may enable us to better risk stratify and optimize our recommendations for

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subsequent COVID-19 vaccination after immediate allergic reactions. As experiences accumulate, similar to the revised algorithm included in this study, we will update our clinical approach to provide up-to-date guidance for individuals with a presumed reaction to the first dose of the mRNA COVID-19 vaccine.

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Figure 1: Patients who were skin tested due to symptoms after mRNA COVID-19 vaccination that were concerning for an allergic reaction. **A:** All patients. **B:** Patients with immediate allergic reactions. **C:** Patients with delayed allergic reactions

[*]3 patients who had positive skin testing to both PEG and polysorbate are represented in the PEG category only in this figure.

[†]1 patient did not receive the next dose in the series and instead received Janssen.

[‡]2 patients had a grade 0 reactions. 1 patient had a grade 1 reaction.

[§]3 patients had a grade 0 reaction. 9 patients had a grade 1 reaction, and 3 patients had a grade 2 reaction.

[‖]2 patients who had positive skin testing to both PEG and polysorbate are represented in the PEG category only for the purpose of this figure.

[¶]1 patient did not receive the next dose in the series and instead received Janssen.

[#]1 patient had a grade 0 reaction. 1 patient had a grade 1 reaction.

[**]2 patients had a grade 0 reaction. 8 patients had a grade 1 reaction. 3 patients had a grade 2 reaction.

[††]1 patient who had positive skin testing to both PEG and polysorbate is represented in the PEG category only for the purpose of this figure.

[‡‡]1 patient had a grade 0 reaction.

[§§]1 patient had a grade 0 reaction. 1 patient had a grade 1 reaction.

Figure 2: Management of patients who present with symptoms concerning for an allergic reaction to the first dose of mRNA COVID-19 vaccine. Use of Janssen vaccine (if available) may be appropriate following allergic reaction to the first dose of mRNA COVID-19 vaccine if allergy evaluation is not feasible or due to shared decision-making between patient and physician.

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	PEG3350 (Miralax)
Step 1 Epicutaneous	1:100 (1.7mg/mL)
Step 2 Epicutaneous	1:10 (17 mg/mL)
Step 3 Epicutaneous	1:1 (170 mg/mL)

	PEG3350	Polysorbate 80 (Choose One)	
	Miralax	Triamcinolone Acetonide (also contains carboxymethyl-cellulose)	Prevnar 13
Step 1 Epicutaneous	1:100 (1.7mg/mL)	40 mg/ml	1:10
Step 2 Epicutaneous	1:10 (17 mg/mL)		
Step 3 Epicutaneous	1:1 (170 mg/mL)		
Step 4 Intradermal		0.4 mg/ml	1:100
Step 5 Intradermal		4 mg/ml	
Step 5 Intradermal		40 mg/ml	

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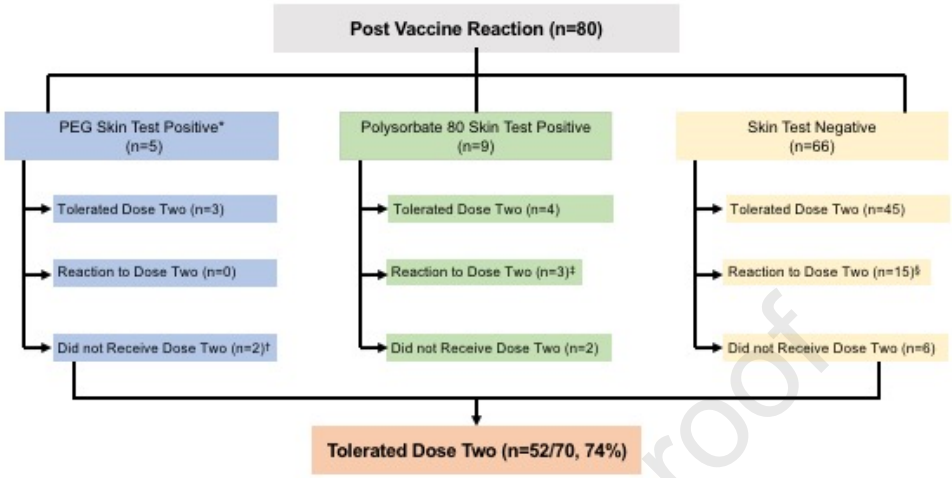

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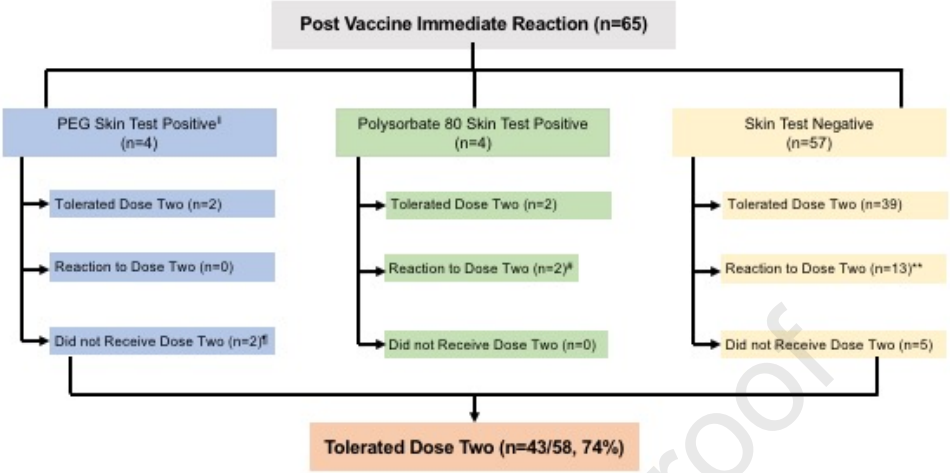

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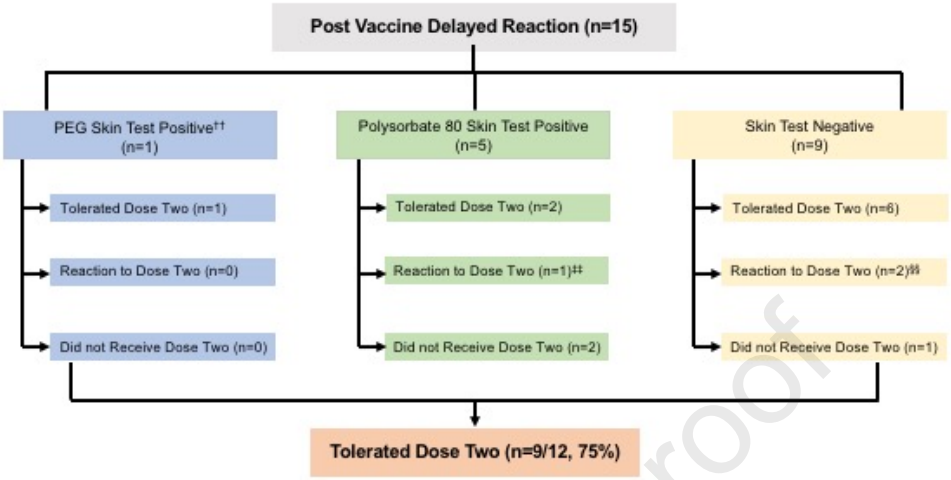

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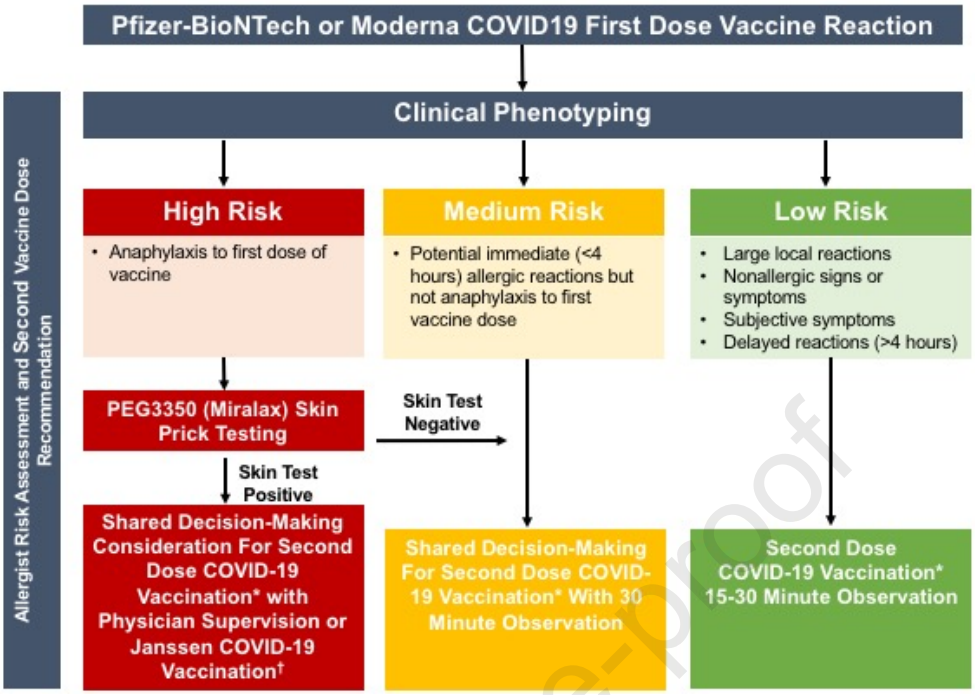

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Table 1. Characteristics of patients that completed skin testing. All patients were referred for skin testing due to symptoms suggestive of an IgE reaction after the first dose of mRNA COVID-19 vaccine.

Characteristic	**All (n=80)**	**Immediate Allergic Reaction[*] (n=65)**	**Delayed Allergic Reaction[†] (n=15)**
Demographics			
Age (mean, SD)	40.9 (±13.6)	42.4 (±12.4)	34.5 (±16.6)
Female Sex (n, %)	71 (89)	57 (88)	14 (93)
Race (n, %)			
White	62 (78)	51 (79)	11 (73)
Asian	7 (9)	5 (8)	2 (13)
Black or African American	4 (5)	3 (5)	1 (7)
Other	7 (9)	6 (9)	1 (7)
History of Atopy (n, %)	56 (70)	45 (69)	11 (73)
Food Allergy	29 (36)	24 (37)	5 (33)
Asthma	25 (31)	19 (29)	6 (40)
History of Anaphylaxis	22 (28)	17 (26)[‡]	5 (33)[§]
Allergic Rhinitis	20 (25)	15 (23)	5 (33)
History of Polysorbate Allergy	5 (6)	3 (5)	2 (13)
Atopic Dermatitis	4 (5)	3 (4.6)	1 (6.7)
History of PEG Allergy	2 (3)	2 (3)	0 (0)
Reaction History (n, %)			
Cutaneous Symptoms[‖]	65 (81)	51 (78)	14 (93)
Lower Respiratory Symptoms[¶]	18 (23)	14 (22)	4 (27)
Cardiovascular Symptoms[#]	11 (14)	10 (15)	1 (7)
Gastrointestinal Symptoms[**]	9 (11)	7 (11)	2 (13)
Upper Airway Symptoms[††]	6 (8)	6 (9)	0 (0)
Other Symptoms	51 (64)	21 (32)[‡‡]	1 (7)[§§]
Management of Allergic Reaction (n, %)			
Antihistamines	54 (68)	47 (72)	7 (47)
Corticosteroids	12 (15)	11 (17)	1 (7)
Epinephrine IM	6 (8)	6 (9)	0 (0)
Emergency Room Visit	19 (24)	18 (28)	1 (7)
Allergic Reaction to (n, %)			
Dose 1 (Moderna)	62 (78)	48 (74)	14 (93)
Dose 1 (Pfizer)	18 (23)	17 (26)	1 (7)
Ring and Messmer Criteria[17] (n, %)			
Grade 0	22 (28)	21 (32)	1 (7)
Grade 1	46 (58)	33 (51)	13 (87)
Grade 2	12 (15)	11 (17)	1 (7)
Positive Skin Test Results (n, %)	14 (18)	8 (65)	6 (40)
Miralax 1:100 (SPT)	1 (1)	1 (2)	0 (0)

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Miralax 1:10 (SPT)	0 (0)	0 (0)	0 (0)
Miralax 1:1 (SPT)	0 (0)	0 (0)	0 (0)
Depo-Medrol 0.4mg/mL (IDT)	3 (4)	2 (3)	1 (7)
Depo-Medrol 4mg/mL (IDT)	1 (1)	1 (2)	0 (0)
Refresh Eye Drops 1:1 (SPT)	0 (0)	0 (0)	0 (0)
Refresh Eye Drops 1:100 (IDT	10 (13)	5 (8)	5 (33)
Refresh Eye Drops 1:10 (IDT)	2 (3)	1 (2)	1 (7)

[*] Immediate was defined as 4 or fewer hours. 47 (72%) were within 1 hour, with a median of 10 minutes (IQR: 5,15)
[†] Delayed was defined as more than 4 hours. 11 (73%) were within 24 hours
[‡] Medication 9 (14), Food 6 (9), Venom 2 (3)
[§] Medication 3 (20), Food 2 (13)
[ǀ] Hives, rash, itching, swelling (not throat), flushing
[¶] Wheezing, chest tightness, shortness of breath, cough
[#] Tachycardia, hypotension
[**] Gastrointestinal upset, diarrhea, vomiting, nausea
[††] Throat swelling, hoarseness, globus
[‡‡] Tingling (n=14, 22%), lightheaded (n=4, 6%), chest pain (n=1, 2%), feeling hot (n=1, 2%), and syncope (n=1, 2%), red eye (n=1, 2%). Patients may have more than one symptom.
[§§] Sneezing (n=1, 7%), tingling (n=1, 7%). Patients may have more than one symptom.
Abbreviations: Coronavirus Disease-2019, COVID-19 Standard Deviation, SD; Polyethylene Glycol, PEG; Interquartile range, IQR; Skin prick test, SPT; intradermal test, IDT; Intramuscular, IM

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Table 2. Patients with positive skin testing results. Clinical characteristics, details of first dose reaction, skin testing result, and details of second dose for patients with positive skin testing results.

	Age	Sex	Past History		Dose One Reaction						Skin Test Results	Dose Two Outcome
			Allergies or Allergic Reaction	Prior History of Anaphylaxis	Vaccine	Onset of Symptoms	Signs and Symptoms	Treatment	Treatment Setting/ Disposition	Ring and Messmer Grade		
Immediate (<4 hour) Reaction	46	F	Hymenoptera venom	Yes: Hymenoptera venom	Moderna	0.16 hour	Dizziness, nausea, difficulty swallowing, swelling of eyes and tongue, hives	Diphenhydramine	Home	1	Methyl-prednisolone Acetate IDT 4 mg/ml (10x14mm) Refresh IDT 1:10 (9x21mm)	Tolerated Janssen.
	40	F	None	No	Pfizer	0.16 hour	Flushing, tachycardia, tongue itching, swelling of fingers, vomiting, diarrhea	Diphenhydramine, IV fluids, epinephrine IM, methyl-prednisolone succinate, ondansetron.	Emergency Department	1	Miralax SPT 1:100 (6x25mm)	Recommended to not receive dose two.
	26	F	Ginger	No	Moderna	0.25 hour	Wheezing	No treatment needed	Home	2	Methyl-prednisolone Acetate IDT 0.4 mg/ml (16x44mm)	Tolerated Moderna
	56	F	Omalizumab, cefaclor, sulfonamide antibiotics, nuts, shellfish, latex	No	Moderna	0.3 hour	Stinging in eyes, tingling of the tongue and lips, mild itching	Cetirizine, famotidine	Home	0	Refresh IDT 1:100 (8x11mm)	Pretreated with cetirizine 10mg and prednisone 20mg. 5 minutes after receiving dose two (Moderna), patient experienced pruritus. Treated with cetirizine 20mg.
	49	F	None	No	Moderna	1 hour	Flushing, hives, itching	Fexofenadine	Home	1	Refresh IDT (5x15mm)	Tolerated Moderna.

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	26	F	Environmental	No	Moderna	3 hours	Wheezing, chest tightness, dry cough	Albuterol	Home	2	Methyl-prednisolone Acetate IDT 0.4 mg/ml (10x20mm) Refresh IDT 1:100 (8x18mm)	Tolerated Moderna.
	54	M	None	No	Moderna	3 hours	Itching, lip swelling	No treatment needed	Home	1	Refresh IDT 1:100 (9x21mm)	4-6 hours after receiving dose two (Moderna), patient experienced lip swelling, which self-resolved.
	42	F	Penicillin, hymenoptera venom	No	Moderna	4 hours	Hives	No treatment needed	Home	1	Refresh IDT 1:100 (6x24mm)	Tolerated Moderna
Delayed (>4 hour) Reaction	28	F	None	No	Moderna	10-12 hours	Itching, hives	No treatment needed	Home	1	Refresh IDT 1:100 (4x12mm)	Awaiting vaccination
	29	F	Penicillin	No	Moderna	12-16 hours	Palpitations, diarrhea, delayed hives	Loperamide	Home	0	Refresh IDT 1:100 (7x18mm)	Tolerated Moderna.
	33	F	None	No	Moderna	12-24 hours	Diffuse hives	Diphenhydramine	Home	1	Refresh IDT 1:100 (10x40mm)	Tolerated Moderna.
	24	F	Environmental	No	Moderna	18-24 hours	Wheezing, chest tightness, hives, itching	Diphenhydramine, topical hydrocortisone	Home	1	Methyl-prednisolone Acetate IDT 0.4 mg/ml (9x22mm) Refresh IDT 1:100 (13x32mm)	Tolerated Moderna.
	49	F	None	No	Pfizer	20 hours	Tongue swelling, sneezing, nasal congestion, itchy eyes, chest	Diphenhydramine, Acetaminophen, Pseudoephedrine	Home	1	Refresh IDT 1:100 (12x20mm)	Patient preference to not receive dose 2.

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							congestion, cough, swelling of fingers					
	19	F	Peanut, tree nuts	Yes: peanut, tree nut	Moderna	48 hours	Hives, “throat closing”	Diphenhydramine	Home	1	Refresh IDT 1:10 (11x17mm)	Pretreated with cetirizine 10mg and prednisone 20mg. 20 minutes after receiving dose two (Moderna), patient experienced dizziness, numbness in legs and fingers, warm feeling in throat. Treated with cetirizine 10mg.

Table 3. Patients with negative skin testing results but reported a reaction to dose two. Clinical characteristics, details of first dose reaction and details of second dose reaction for patients with negative skin testing results who developed a reaction to dose two. *Ring and Messmer Grade.[13]

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	Age	Sex	Allergies or Allergic Reaction	Vaccine	Dose One Reaction				Dose Two Reaction			
					Onset of Symptoms	Signs and Symptoms	Treatment and Treatment Setting	Grade*	Onset of Symptoms	Signs and Symptoms	Treatment and Treatment Setting	Grade*
Immediate (<4 hours) Reaction	29	F	Cefuroxi-me, sulfon-amide antibiotics, clindamy-cin, iodinated contrast media, ketocon-azole, moxiflox-acin, nystatin	Moderna	0 hours	Dizziness, fatigue, hives	Levocetirizine and diphenhydramine at home	1	0.2 hours	Hives	Diphenhydramine at the vaccine clinic and cetirizine, famotidine, and prednisone at home	1
	62	F	Sulfon-amide antibiotics, latex, loratadine, morphine	Moderna	0.1 hours	Lip tingling, dizziness, eye and facial swelling	No treatment was sought	1	0.5 hours	Itching of ear, eye swelling	Diphenhydramine at the vaccine clinic and prednisone at home	1
	56	M	No known allergies	Pfizer	0.1 hours	Tongue tingling, lower lip swelling, mild throat clearing	Epinephrine, diphenhydramine, solumedrol at the emergency department	1	0.1 hours	Lower lip swelling	Cetirizine at home	1
	47	F	Latex, tramadol, amoxicillin , sulfameth-oxazole-trimetho-prim, flucona-zole	Moderna	0.1 hours	Itching, lip tingling, subjective lip and tongue swelling, hive-like rash	Diphenhydramine at the vaccine clinic and loratadine and cetirizine at home	1	12 hours	Eye swelling and itching	Loteprednol and cetirizine at home	1
	56	F	Shrimp,	Moderna	0.1 hours	Generalized	Diphenhydramine at	0	0.2 hours	Itching,	Diphenhydramine at	0

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			nitofuran-toin, ibuprofen, sulfamex-thoxazole-trimetho-prim			itching, throat itchiness, fatigue	the emergency department and albuterol at home			headache, throat tightness and itching, warmth, flushing	the emergency department	
	57	F	No known allergies	Moderna	0.1 hours	Headache, throat tightness, fatigue, hypertension, redness on legs, joint and muscle aches, shakes	Ibuprofen and unspecified antihistamine at home	0	12-24 hours	Itching, rash, diarrhea, vomiting, headache, fatigue, fever, cough, muscle aches, and joint pain	Acetaminophen and diphenhydramine at home	1
	46	F	Pepper, procaine	Moderna	0.2 hours	Tingling of left arm, roof of mouth, and tongue, numbness.	Cetirizine at the emergency department	0	0 hours	Numbness, chest tightness, dry heaving, chills, hot sensation in lips	Diphenhydramine, ondansetron, and methylprednisolone at the emergency department	0
	24	F	Amoxi-cillin, clinda-mycin, pineapple, benzo-natate	Moderna	0.25 hours	Globus and throat itching, cough, erythemat-ous oropharynx, hoarse voice	Epinephrine, methylprednisolone sodium succinate, and diphenhydramine at the emergency department	2	0.6 hours	Throat tightness and itching, cough, erythematous posterior pharynx, watery eyes	Cetirizine, albuterol, and epinephrine at the vaccine clinic and methylprednisolone sodium succinate, diphenhydramine, and famotidine at the emergency department	2
	29	F	MMR vaccine, penicillin	Pfizer	0.3 hours	Hives, cough, hoarseness	Epinephrine, prednisone, and cetirizine at the emergency department	2	0.3 hours	Itching, rash, hives, throat tightness, cough	Epinephrine, cetirizine, and albuterol at the emergency department	2
	58	F	Ciproflox-	Moderna	0.5 hours	Lip tingling,	No treatment was	1	12 hours	Lip tingling,	Unspecified	1

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			acin, cephalex-in, macrolide antibiotics, NSAIDs, omepra-zole, penicillin, theophyll-ine, codeine			eye, lip, facial, and leg swelling, throat tightness	sought			lip swelling, sensation of facial swelling	antihistamine at home	
	59	F	Succinyl-choline, midazolam, prometha-zine, gabapentin, fentanyl, prochlor-perazine, cefazolin	Pfizer	1.25 hours	Sensation of throat closing, dysphagia, shortness of breath, itching of palms, soles, and torso	Diphenhydramine at the vaccine clinic	0	0.3 hours	Face, neck, and chest flushing, itching over palms and feet, lip fullness and tingling	Diphenhydramine at the vaccine clinic	1
	43	F	Ibuprofen, penicillin	Pfizer	2 hours	Lip swelling, full body itching, facial swelling, headache	Acetaminophen at home	1	0.75 hours	Tongue numbness, hive-like rash, wheezing	No treatment was sought	2
	43	F	No known allergies	Moderna	2-3 hours	Itchy rash on right arm, red and itchy right eye	No treatment was sought	1	0.1 hours	Chest flushing	No treatment was sought	1
hour	37	F	Cephal-osporins,	Moderna	8.5 hours	Hives, eye and lip	Diphenhydramine and loratadine at	1	0.25 hours	Arm and neck itching,	Cetirizine in the vaccine clinic	0

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			penicillin, shellfish, latex, bee sting, influenza vaccine			swelling	home			arm erythema		
	62	F	Iodine, shellfish	Moderna	10 hours	Hives, nausea, diarrhea	Unspecified anti-itch cream at home	1	Unknown	Throat, tongue, and eye swelling, itching of chest and face, nausea, headache, lethargy	No treatment was sought	1

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Figure E1: Skin testing protocol for PEG using Miralax for epicutaneous testing without PEG intradermal testing and PEG and polysorbate 80.

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Table E1: Skin testing protocols used in the manuscript to test for PEG and polysorbate 80 allergy.[13] Refresh Tears, which contains polysorbate 80 0.5%, was subsequently found to be irritating. Triamcinolone acetonide contains polysorbate 80 0.04%. *Some brands of methylprednisolone acetate contain polysorbate and PEG3350 while others only have PEG3350; use methylprednisolone acetate containing PEG3350 only.

Drug	SPT (mg/mL)	ID (mg/mL)
PEG-3350		
Miralax	1.7 17 170	
Methyl-prednisolone acetate*	40	0.4 4
Control		
Methyl-prednisolone sodium succinate	40	0.4 4
Polysorbate 80		
Triamcinolone acetonide	40	0.4 4 40
Refresh Tears	1:1	1:10

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Table E2: Ring and Messmer Grading for allergic reactions.[21]

Grade 1: Cutaneous Signs
Urticaria
Angioedema
Generalized Erythema
Grade 2: Measurable but not life-threatening symptoms
Cutaneous signs
Hypotension (defined as a decrease of more than 30% in blood pressure with tachycardia)

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Cough
Difficulty with mechanical ventilation
Grade 3: Life-threatening symptoms
Cardiovascular collapse
Tachycardia or bradycardia (due to not include mild sinus tachycardia)
Arrhythmias
Severe bronchospasm
Grade 4: Death
Cardiac arrest
Respiratory arrest

Table E3: Refresh Tears skin testing results on non-allergic, clinically tolerant controls, reflecting a high frequency of false positive, irritant reactions. Among 25 non-allergic controls, there were 13 (52%) positive reactions to Refresh Tears on intradermal testing, with 8 (32%) positive at the 1:100 concentration and 5 (20%) positive at the 1:10 concentration

Patient	Refresh Tears 1:100 (ID) (mm, wheal x flare)	Refresh Tears 1:10 (ID) (mm, wheal x flare)
1	10 x 20	--
2	0	7 x 15
3	0	8 x 18
4	0	0
5	8 x 18	--
6	9 x 14	--
7	0	0
8	0	0
9	0	0
10	0	0
11	8 x 13	--
12	0	0
13	9 x 20	--
14	0	7 x 18
15	0	0
16	0	--
17	0	--

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18	0	6 x 24
19	0	0
20	0	0
21	0	0
22	8 x18	--
23	7 x 8	--
24	0	4 x 8
25	5 x 10	--
Total:	8 (32%)	5 (20%)

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