Increased ratio of pollock roe-specific IgE to salmon roe-specific IgE levels is associated with a positive reaction to cooked pollock roe oral food challenge

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A B S T R A C T

Background: Anaphylaxis and immediate-type fish roe allergies have been reported worldwide, and, in Japan, fish roe is the sixth most common food allergen. No oral food challenges (OFCs) have used pollock roe (PR), which is reported to have high cross-reactivity with salmon roe (SR). Therefore, we administered an OFC using cooked PR to evaluate PR- and SR-specific immunoglobulin E (IgE) levels and allergic reactions in patients with PR sensitivity.

Methods: This retrospective study evaluating patient characteristics and responses to OFCs was conducted with 10–20 g of cooked PR, between April 2006 and November 2016.

Results: We assessed 51 patients (median age: 6.8 years). All had PR sensitization, 6 (12%) with a history of immediate reactions to PR, and 18 (35%) of immediate reactions to SR. Median PR-specific and SR-specific IgE values were 3.4 kUA/L and 9.9 kUA/L, respectively. Seven patients (14%) had a positive OFC. There was no anaphylaxis. Induced symptoms were mild and included localized urticaria, throat pruritus, intermittent cough, and mild abdominal pain. We treated one patient with mild abdominal pain with oral antihistamines. There were no significant differences in history of immediate reaction to PR and PR-specific IgE titers between OFC-positive and OFC-negative patients, although significant differences were found for PR-specific IgE titers adjusted for SR-specific IgE (p = 0.025) and PR-specific IgE/SR-specific IgE ratio (p = 0.009).

Conclusions: Increased PR-specific IgE/SR-specific IgE ratio or PR-specific IgE levels adjusted for SR-specific IgE levels were risk factors for OFC positivity.

Introduction

In Japan, fish roe is the sixth most common food allergen. Moreover, among new-onset immediate-type food allergies, fish roe is the most common food allergen of 2- to 3-year-old children.

Fish roe used in cooking includes caviar, herring roe, salmon roe (SR), pollock roe (PR), and flying fish roe. In Japan, SR is often ingested in the form of sushi rolls. PR is a popular food in Japan and Korea, and is often an ingredient in rice balls and pasta sauces, which are frequent components of Japanese food. In Sweden, processed roe of Pacific cod, which belongs to the same family as pollock, is commonly served.

Cases of immediate-type allergy and anaphylaxis in reaction to caviar and SR have been reported worldwide. In Japan, the majority of allergic reactions to fish roe are to SR, and there has been one report of an SR oral food challenge (OFC). However, there have been no reports of cross-reactivity between PR and SR on an OFC.

PR is often served cooked in school meals and in meals eaten out in Japan; therefore, if children with suspected PR allergy could eat cooked PR, their quality of life would improve. Thus, the aim of our study was to evaluate the safety of an OFC with cooked PR and to evaluate the risk factors for OFC positivity.

Footnotes

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Methods

Subjects

We retrospectively evaluated PR-sensitized patients who had undergone an OFC with 10–20 g of cooked PR to diagnose a PR allergy or confirm their tolerance, between April 2006 and November 2016. Sensitization to PR was defined as PR-specific immunoglobulin E (IgE) > 0.35 (kUA/L) observed within one year prior to the OFC.

Methods

The total amount of challenge food was 10–20 g of cooked PR (protein: 2830–5660 mg), which was cooked either at the Sagamihara National Hospital or in the patients’ homes. Patients who had been prescribed anti-allergy drugs (e.g., antihistamines) were excluded from the study because they could influence the results of the OFC. This OFC involving PR was an open challenge, because PR is usually eaten in a simple cooked form. We employed three different protocols in our study. For the first, the dosing interval was 15 min, and five doses were administered, starting with 1/16 of the total load, followed by 1/8, 1/4, and 1/2. For the second protocol, the dosing interval was 30 min, and three doses were administered, starting with 1/8 of the total load, followed by 3/8 and 1/2. For the third protocol, the dosing interval was 60 min, and two doses were administered, starting with 1/4 of the total load, followed by 3/4. Until March 2014, we used the first protocol in our inpatient department and the second in our outpatient department. However, from April 2014, we used the third protocol for all patients. Follow-up of patients for 3 h from the beginning of the OFC.

Positive symptoms of OFC were defined as skin symptoms (urticaria, exanthema, and pruritus), oral mucosal symptoms (pruritus of the throat or oral cavity), respiratory symptoms (cough, wheezing, hoarseness, and dyspnea), gastrointestinal symptoms (emesis, diarrhea, and persistent abdominal pain), cardiovascular symptoms (hypotension), and neurological symptoms (confusion), as reported by Sampson et al.11 The severity of symptoms was evaluated using the Japanese anaphylaxis guidelines (Supplementary Table 1).12 When adverse symptoms occurred, treatments such as antihistamines, steroids, beta-2 stimulant inhalation, or adrenaline injection were administered. However, from April 2014, we used the third protocol for all patients. Follow-up of patients for 3 h from the beginning of the OFC.

Measurement of serum-specific IgE

Patients’ PR, SR, hens’ egg white, and codfish-specific IgE titers were measured using the Immuno-CAP assay system (Thermo Fisher Scientific, Uppsala, Sweden). Specific IgE titers >0.35 kUA/L were considered positive.

Statistical analysis

Patients’ characteristics and immunological parameters were evaluated, and the results were expressed as the median and interquartile range. For statistical comparisons between the two groups, we used Mann–Whitney U tests for continuous variables and Fisher’s exact tests for categorical variables. P-values <0.05 were considered significant.

Receiver operating characteristic (ROC) curves were generated for PR-specific IgE levels and PR-specific IgE/SR-specific IgE ratios. Performance of the model was assessed using the area under the curve (AUC). Specificity and sensitivity were calculated for each cut-off value. We analyzed the relationship between OFC results and PR or SR-specific IgE levels using logistic regression.

Probability curves and 95% confidence intervals (CIs) were estimated from PR-specific IgE values and PR-specific IgE/SR-specific IgE ratios using logistic regression according to the methods used by Soderstro et al. and Grabenhenrich et al.11 All data were statistically analyzed using SPSS version 24 (IBM, Armonk, NY, USA).

Ethical considerations

In accordance with the tenets of the Declaration of Helsinki, the study design and the risks of symptom provocation were fully explained to the patients and the children’s guardians both verbally and in writing. Written informed consent was obtained from the guardians prior to participation. The study design was approved by the institutional review board of Sagamihara National Hospital.

Results

Baseline subject characteristics

Sixty-five patients underwent OFCs with 10–20 g of cooked PR. The following 14 patients were excluded: 13 patients who had no sensitization and no history of immediate reaction, and 1 patient for whom PR-specific IgE had not been measured. Therefore, we analyzed 51 patients in total (Fig. 1).

Table 2 shows patients’ characteristics and immunological parameters. The median age of all patients was 6.8 years, and 59% were male. Six patients (12%) had a history of immediate reactions to PR, and 1 patient (2%) had a history of anaphylaxis to PR. Forty-five patients (88%) were already avoiding SR due to possible cross-reactivity with PR. Forty-five patients (88%) had a history of immediate reactions to SR. Twenty-nine patients (57%) had a history of immediate reactions to hens’ egg whites. Complications from other allergic diseases included atopic dermatitis (24 patients, 47%), bronchial asthma (9 patients, 18%), and allergic rhinitis (6 patients, 12%).

The median total IgE value was 1460 kIU/L, the SR-specific IgE value was 3.4 kUA/L, the PR-specific IgE value was 9.9 kUA/L, and the hens’ egg white-specific IgE value was 11.7 kUA/L, and the codfish-specific IgE value was 0.18 kUA/L.

Relationship of specific IgE values

Figure 2 shows the relationship-specific IgE values between PR and SR, PR and hens’ egg whites, and PR and codfish. We found moderate positive correlations between PR and SR (R = 0.583, p-value<0.001) (Fig. 2 A). However, there were no significant correlations found between PR and hens’ egg whites (R = 0.254, p-value = 0.088), and PR and codfish (R = 0.262, p-value = 0.147) (Fig. 2 B, C).

OFC results

Seven patients (14%) had positive OFC results to cooked PR. Table 2 shows the induced symptoms, severity, and treatments for these patients. The most common positive symptoms were oral mucosal symptoms, followed by skin, gastrointestinal, and respiratory symptoms. All positive patients (n = 7) had Grade-1 (mild) symptoms. One patient who presented with pruritus of
The throat and mild abdominal pain was treated with an oral antihistamine. Although 1 in 7 OFC-positive patients had no symptoms in the hospital setting, 1 patient had mild abdominal pain and emesis due to consuming cooked PR at home (Table 2, Supplementary Table 2).

We examined patients’ characteristics and immunological parameters in relation to positive and negative results (Table 3). No significant differences were observed for age, sex, history of immediate reactions to PR and SR, complications of other allergic diseases, or values of specific IgE (PR, SR, hens’ egg whites, and codfish). However, OFC-positive patients had significantly higher PR-specific IgE/SR-specific IgE ratios than did negative patients ($p = 0.009$) (Table 3, Supplementary Fig. 1).

One of the negative OFC patients underwent an OFC with raw PR after the OFC with cooked PR, and had positive OFC results with the raw PR. Other patients did not request an OFC with raw PR. Subsequently, we were not able to confirm whether or not those patients could eat raw PR at home.

### ROC analysis

The AUC for PR-specific IgE was 0.636, whereas the AUC for PR-specific IgE/SR-specific IgE ratio was 0.803 (Fig. 3). The AUC for the PR-specific IgE/SR-specific IgE ratio was higher than that for PR-specific IgE. For the PR-specific IgE/SR-specific IgE ratio at an optimal cutoff of 0.47 (Youden index), we obtained values of 73.8% (specificity), 71.4% (sensitivity), 31.2% (positive predictive value, PPV), and 93.9% (negative predictive value, NPV). At a cutoff of 0.2, we obtained values of 45.2% (specificity), 100% (sensitivity), 23.3% (PPV), and 100% (NPV). At a cutoff of 1.3, we obtained values of 97.6% (specificity), 42.9% (sensitivity), 75.0% (PPV), and 91.1% (NPV) (Supplementary Table 3).

### Multivariate analysis and probability curves

When OFC-positive and OFC-negative patients were compared, no significant differences were observed for PR-specific IgE as determined by using univariate analysis. Nevertheless, results from multivariate logistic regression analysis indicated that high PR-specific IgE levels were significant risk factors for a positive OFC adjusted for SR-specific IgE (adjusted odds ratio: 20.2 per 10-fold increase [95% CI, 1.45–283.0]; $p = 0.025$) (Table 4).

Fitted probability curves for the relationships between OFC outcomes and PR-specific IgE values or PR-specific IgE/SR-specific IgE ratios are presented in Figure 4. The curve shows that a PR-specific IgE/SR-specific IgE ratio of 0.16 indicates a 5% PPV, a ratio of 0.31 indicates a 10% PPV, a ratio of 0.61 indicates a 20% PPV, and a ratio of 1.94 indicates a 50% PPV. We were unable to calculate the value for more than 70% PPV, because there were no applicable patients.

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**Table 1**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total ($n = 51$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex (%)</td>
<td>30 (59)</td>
</tr>
<tr>
<td>Median age at challenge (years)</td>
<td>6.8 (4.6–9.0)</td>
</tr>
<tr>
<td>History of immediate reactions to PR (%)</td>
<td>6 (12)</td>
</tr>
<tr>
<td>History of anaphylaxis to PR (%)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Avoiding SR (%)</td>
<td>45 (88)</td>
</tr>
<tr>
<td>History of immediate reactions to PR (%)</td>
<td>18 (35)</td>
</tr>
<tr>
<td>History of immediate reactions to SR (%)</td>
<td>29 (57)</td>
</tr>
<tr>
<td>Atopic dermatitis, current (%)</td>
<td>24 (47)</td>
</tr>
<tr>
<td>Bronchial asthma, current (%)</td>
<td>9 (18)</td>
</tr>
<tr>
<td>Allergic rhinitis, current (%)</td>
<td>6 (12)</td>
</tr>
<tr>
<td>Total IgE (kIU/L)</td>
<td>1460 (529–2470)</td>
</tr>
<tr>
<td>PR-specific IgE (kUA/L)</td>
<td>3.45 (1.36–6.50)</td>
</tr>
<tr>
<td>SR-specific IgE (kUA/L)</td>
<td>9.95 (4.90–28.80)</td>
</tr>
<tr>
<td>PR-specific IgE/SR-specific IgE</td>
<td>0.26 (0.12–0.61)</td>
</tr>
<tr>
<td>Egg white-specific IgE (kUA/L)</td>
<td>11.70 (1.23–41.30)</td>
</tr>
<tr>
<td>Codfish-specific IgE (kUA/L)</td>
<td>0.185 (0.05–0.562)</td>
</tr>
</tbody>
</table>

Data are presented as medians (with interquartile range: 25–75 percentiles) or n (%).

1 n = 49.
2 n = 46.
3 n = 32.
the challenge level for the OFC.

- Typically eats is 10
- cooked PR contains 283 mg/g. The amount of PR that one person
- cooked PR are edible. Raw PR contains 240 mg/g of protein, and
- was 54%, which was more than half of all patients. In contrast,
- had a history of immediate reactions to SR, and the median
- age of all patients was 6.7 years, 39% of all patients
- underwent OFCs with 10 g of raw SR. In that study,
- our report, 62 patients with suspected or confirmed SR
- allergy underwent OFCs with 10 g of raw SR. In that study,
- the median age of all patients was 6.7 years, 39% of all patients
- had a history of immediate reactions to SR, and the median
- SR-specific IgE value was 3.4 kUA/L. The positivity rate for the OFC
- was 54%, which was more than half of all patients. In contrast,

Discussion

Our study is the first report of an OFC using cooked PR. PR-
sensitized patients, who underwent an OFC with 10–20 g of
cooked PR in order to diagnose a PR allergy or confirm their
tolerance, were evaluated. At 14%, the positivity rate for the OFC
was low. An increased PR-specific IgE/SR-specific IgE ratio or
increased PR-specific IgE levels adjusted for SR-specific IgE levels
were shown to be risk factors for OFC positivity.

PR is the salted ovary of Alaskan pollock (Thera
gus chalcog-
fram). In Japan, PR is commonly served as an ingredient in rice
balls, traditional Japanese foods, and pasta sauces. Both raw
and cooked PR are edible. Raw PR contains 240 mg/g of protein,
and cooked PR contains 283 mg/g. The amount of PR that one
person typically eats is 10–20 g. Therefore, we selected 10–20 g of PR as
the challenge level for the OFC.

Yanagida et al. have reported on OFCs with raw SR. In
their report, 62 patients with suspected or confirmed SR
allergy underwent OFCs with 10 g of raw SR. In that study,
the median age of all patients was 6.7 years, 39% of all patients
had a history of immediate reactions to SR, and the median
SR-specific IgE value was 3.4 kUA/L. The positivity rate for the OFC
was 54%, which was more than half of all patients. In contrast,

Table 2

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td></td>
</tr>
<tr>
<td>Oral mucosal symptoms</td>
<td>6 (86%)</td>
</tr>
<tr>
<td>Skin symptoms</td>
<td>3 (43%)</td>
</tr>
<tr>
<td>Gastrointestinal symptoms</td>
<td>2 (29%)</td>
</tr>
<tr>
<td>Respiratory symptoms</td>
<td>1 (14%)</td>
</tr>
<tr>
<td>Severity</td>
<td></td>
</tr>
<tr>
<td>Grade 1 (mild)</td>
<td>7 (100%)</td>
</tr>
<tr>
<td>Grade 2 (moderate)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Grade 3 (severe)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
</tr>
<tr>
<td>Antihistamine (oral)</td>
<td>1 (14%)</td>
</tr>
<tr>
<td>No treatment</td>
<td>6 (86%)</td>
</tr>
</tbody>
</table>

The definitions of severity grade were based on anaphylaxis guidelines.

1 Although 1 of the 7 OFC-positive patients showed no symptoms in the hospital setting, that patient had mild abdominal symptoms later from consuming cooked PR at home.

Table 3

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OFC-positive (n = 7)</th>
<th>OFC-negative (n = 44)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex (%)</td>
<td>5 (71)</td>
<td>25 (57)</td>
<td>0.685</td>
</tr>
<tr>
<td>Median age at challenge (years)</td>
<td>5.7 (5.9–5.4)</td>
<td>5.6 (5.4–5.8)</td>
<td>0.117</td>
</tr>
<tr>
<td>History of immediate reactions to PR (%)</td>
<td>1 (14)</td>
<td>5 (11)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>History of anaphylaxis to PR (%)</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Avoiding SR (%)</td>
<td>6 (86)</td>
<td>39 (89)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>History of immediate reactions to SR (%)</td>
<td>3 (43)</td>
<td>15 (34)</td>
<td>0.868</td>
</tr>
<tr>
<td>History of immediate reactions to hens’ eggs (%)</td>
<td>5 (71)</td>
<td>24 (55)</td>
<td>0.684</td>
</tr>
<tr>
<td>Atopic dermatitis, current (%)</td>
<td>3 (43)</td>
<td>19 (43)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Bronchial asthma, current (%)</td>
<td>2 (29)</td>
<td>7 (16)</td>
<td>0.392</td>
</tr>
<tr>
<td>Allergic rhinitis, current (%)</td>
<td>1 (14)</td>
<td>5 (11)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Total IgE (kUA/L)</td>
<td>1390 (1085–3200)</td>
<td>1495 (445–2402)</td>
<td>0.477</td>
</tr>
<tr>
<td>PR-specific IgE (kUA/L)</td>
<td>3.52 (2.45–14.25)</td>
<td>3.18 (1.10–5.81)</td>
<td>0.239</td>
</tr>
<tr>
<td>SR-specific IgE (kUA/L)</td>
<td>5.94 (4.45–8.88)</td>
<td>13.55 (4.98–47.00)</td>
<td>0.219</td>
</tr>
<tr>
<td>PR-specific IgE/SR-specific IgE</td>
<td>1.08 (0.36–1.43)</td>
<td>0.25 (0.10–0.53)</td>
<td>0.009</td>
</tr>
<tr>
<td>Egg white-specific IgE (kUA/L)</td>
<td>44.40 (14.40–47.00)</td>
<td>10.30 (4.50–9.40)</td>
<td>0.198</td>
</tr>
</tbody>
</table>

Data are presented as medians (25–75 percentiles) or n (%). Differences were evaluated using the Mann–Whitney test for continuous variables or the Fisher’s exact test for categorical variables.

No significant differences were observed for age, sex, history of immediate reactions to PR and SR, complications of other allergic diseases, and values of specific IgE (PR, SR, hen’s egg white, and codfish). OFC-positive patients had significantly higher PR-specific IgE/SR-specific IgE ratios than did negative patients (p = 0.009).

In our study, the positivity rate for the OFC with 10–20 g of cooked PR was 14%, which is relatively low. In addition, induced symptoms were mild, and only one patient was treated with oral antihistamines.
Yanagida et al. also reported that SR-specific IgE is useful to estimate positive OFCs with SR. However, in our comparisons between OFC-positive and OFC-negative patients, no significant differences were observed for PR-specific IgE. Nevertheless, PR-specific IgE levels adjusted for SR-specific IgE were considered to be significant risk factors for OFC positivity. Moreover, OFC-positive patients had significantly higher PR-specific IgE/SR-specific IgE ratios than did OFC-negative patients. In our ROC analysis, the PR-

![ROC curves showing the performance of PR-specific IgE/SR-specific IgE and pollock roe-specific IgE.](image)

**Table 4**

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>p-value</th>
<th>Adjusted odds ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-specific IgE (kUA/L) (10-fold increments)</td>
<td>3.55 (95% CI, 0.57 e 22.0)</td>
<td>0.173</td>
<td>20.20 (95% CI, 1.45 e 283.0)</td>
<td>0.0255</td>
</tr>
</tbody>
</table>

1 Adjusted SR-specific IgE.

![Fitted predicted probability curves for the outcome of an oral food challenge at a given IgE level of (A) PR-specific IgE (kUA/L) and (B) PR-specific IgE/SR-specific IgE. Shaded areas indicate the range of the 95% CI. Probabilities for the outcomes of oral food challenges for PR-specific IgE levels and PR-specific IgE/SR-specific IgE ratios were calculated using logistic regression analysis.](image)
specific IgE/SR-specific IgE ratio was more useful than the PR-specific IgE for predicting OFC-positive results.

In our study, the rate of positive results from the cooked PR OFC was low, and symptoms of positive patients were mild. Thus, this OFC is recommended for diagnosing PR allergies. Moreover, if a patient has a PR-specific IgE/SR-specific IgE ratio lower than 0.16 (5% PPV), eating cooked PR at home is acceptable. However, if the patient has a PR-specific IgE/SR-specific IgE ratio higher than 2 (approximately 50% PPV), the OFC should be conducted carefully.

Cross-reactivity between the beta-component of PR and Onc k 5, which is the main allergen of SR, has been identified. To our knowledge, we observed moderate positive correlations between PR-specific IgE and SR-specific IgE. Moreover, we found no significant correlations between PR-specific IgE and hens’ egg white-specific IgE or codfish-specific IgE. These results are consistent with those of previous studies. If the beta-component of PR is the main allergen inducing PR allergy, patients who have positive reactions to PR on OFCs should have high values of both PR- and SR-specific IgE. However, on our OFC, the proportion of patients who had higher levels of SR-specific IgE than PR-specific IgE was low. We suspect that the reason for this is that, in contrast to SR, the beta-component of PR is not the major allergen. However, the specific allergenic components inducing sensitization in our OFC-positive patients are unknown. Our study did not use western blotting to assay sera from patients with positive OFCs. Further analysis to identify the true allergenic components is therefore necessary.

One of the 44 negative OFC patients who underwent an OFC with raw PR after the OFC with cooked PR had positive OFC results with raw PR. Thus, it is possible that the antigenicity of PR decreases when PR is cooked, as is the case with hens’ eggs. To confirm true tolerance, an OFC using raw PR is needed following an OFC with cooked PR. However, most of our patients were satisfied that they could safely eat cooked PR, and, therefore, they felt that their quality of life was improved.

Of the six patients with a history of immediate reaction to PR, five had no reaction to cooked PR on the OFC (Table 3). There are two possible reasons for this: First, the patients may have developed tolerance as they grew older; second, the patients may have experienced an immediate reaction after eating undercooked PR. We do not have detailed information about the methods used to cook the PR eaten by the patients with immediate reactions.

Limitations

Our study has certain limitations. First, the percentage of patients who had a history of immediate reactions to PR was low. Generally, as the percentage of patients with a history of immediate reactions to an allergen becomes higher, the probability of failed OFCs increases. In our study, 11.8% of subjects had a history of immediate reactions to PR, which is lower than that found in a previous study of OFCs to SR. Most subjects in our study underwent this OFC because of sensitization to PR. If the majority of subjects had had a history of immediate reactions to PR, there would have been a possibility that the percentage of positive OFC results and severity of symptoms would have increased. Therefore, further studies using the same OFC but with different study populations are required.

Second, the influence of SR allergy complications was unknown. In our study, most subjects avoided SR because of sensitization to it. However, the percentage of patients with a true SR allergy was unknown because most patients had not undergone an SR OFC. Our study suggests that highly SR-specific IgE, which may cross-react with PR seems to have little influence on PR OFC positivity. Further studies on the relationship between SR allergy complications and PR OFC outcomes are needed. Third, this OFC was an open OFC using cooked PR. A double-blind placebo-controlled food challenge is the gold standard in food allergy diagnosis; however, this would not be realistic for PR because of its very strong taste.

Conclusion

Although all patients had sensitization to PR and some patients had a history of immediate reaction to PR, the positivity rate for the OFC with cooked PR was low. In addition, the symptoms of OFC-positive patients were mild. Thus, this OFC can be recommended to exclude PR allergy. Furthermore, an increased PR-specific IgE/SR-specific IgE ratio or increased PR-specific IgE levels adjusted for SR-specific IgE levels can be considered risk factors for OFC positivity. Therefore, if a patient has a high PR-specific IgE/SR-specific IgE ratio, this OFC should be conducted carefully.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.alit.2017.11.005.

Conflict of interest

The authors have no conflicts of interest to declare.

Authors’ contributions

EM wrote the manuscript. EM, NY, SS, TA, and ME contributed to data collection and analysis. ME organized the study. All authors read and approved the final manuscript.

References

