Leukotriene receptor antagonist addition to intranasal steroid: systematic review and meta-analysis*

Kachorn Seresirikachorn1,2, Joaquim Mullol3, Kanda Limitlaophahan4, Vararuthai Asvapoositkul5, Kornkiat Snidvongs1,2

1 Department of Otolaryngology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand
2 Endoscopic Nasal and Sinus Surgery Excellence Center, King Chulalongkorn Memorial Hospital, Bangkok, Thailand
3 Rhinology Unit & Smell Clinic, ENT Department, Hospital Clinic, IDIBAPS, Universitat de Barcelona, CIBERES, Barcelona, Catalonia, Spain
4 Relief and Community Health Bureau, The Thai Red cross Societies, Bangkok, Thailand
5 Bangkok Metropolitan Administration General Hospital, Bangkok, Thailand

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Abstract
Background: Intranasal corticosteroids (INCS) and leukotriene receptor antagonist (LTRA) have different mechanisms of action. The combination of INCS and LTRA (INCS+LTRA) are utilized to control the allergic rhinitis (AR) symptoms. The effects of this combination have not been made evident yet.

Methodology: Randomized controlled trials studying the effects of INCS+LTRA vs INCS in monotherapy on rhinoconjunctivitis symptoms in patients with AR were included. Data were pooled for meta-analysis. The outcomes were nasal symptoms, ocular symptoms, disease-specific quality of life (QOL), and adverse events.

Results: Six studies (358 participants) met the inclusion criteria. There were no differences between INCS+LTRA and INCS monotherapy on composite nasal symptom score, total daytime symptom score, total night time symptom score, disease-specific QOL and adverse events. The results favoured the effects of INCS-LTRA on ocular symptoms.

Conclusions: The effects of the INCS+LTRA combination are not different from INCS in monotherapy in the improvement of both nasal symptoms and patient’s QOL. The combination may, however, be better on improving ocular symptoms.

Key words: corticosteroids, leukotriene receptor antagonist, allergic rhinitis, asthma

Introduction
With multiple anti-inflammatory activities, intranasal corticosteroid (INCS) is an effective medicine for treating allergic rhinitis (AR). INCS may be prescribed to AR patients with moderate to severe or persistent symptoms having nasal obstruction as major symptom10. INCS binds to a specific cytoplasmic glucocorticoid receptor then activates anti-inflammatory gene transcription and represses pro-inflammatory gene transcription31. As a result, the lymphocyte activation and cytokine production are inhibited, which decrease the migration of inflammatory cells to the nasal mucosa43,44. The anti-inflammatory effects of INCS effectively control the allergic response and relieve the clinical symptoms, including itching, sneezing, rhinorrhea, nasal obstruction, and ocular symptoms.

Leukotriene is a pro-inflammatory mediator which plays a key role in the pathogenesis of AR. In addition to eosinophil chemotaxis, leukotriene release causes vasodilation, increased vascular permeability, smooth muscle constriction and mucus hypersecretion in the airways37-31. Therefore, the effects of leukotriene on the nasal vasculature, such as vascular permeability and vasodilation play a role in producing symptoms of the mucosal swelling31. The related clinical symptoms include nasal obstruction, hypersecretion, bronchoconstriction, and bronchial hyperresponsiveness37. Clinical studies found that topical leukotriene D4 increased blood flow and nasal airway resistance without causing sneezing, rhinorrhea, and nasal itching37-31. Leukotriene receptor antagonist (LTRA) binds to cysteinyll leukotriene 1 (CysLT1) receptor and reduces eosinophilic
inflammation in upper-airway inflammatory diseases such as rhinitis and nasal polyposis(8, 12) and eosinophil chemotaxis (13). CysLTs-induced productions of IL-5 and IL-13 from group 2 innate lymphoid cells (ILC2s) were completely inhibited by CysLT1 antagonist (14). As a result, LTRA reduces nasal inflammation, especially nasal congestion (16). While LTRA decreased T-helper 1 (Th1) cells and increased T-regulatory (Treg) cells in peripheral blood, INCS decreased Th1 cells and Th2 and increased Treg cells in nasal mucosa (15). In addition, eosinophil cationic protein (ECP), histamine, and cysteinyl-leukotrienes (CysLTs) were significantly decreased greater by INCS and INCS+LTRA treatments than LTRA monotherapy. This trend was reflected with combination therapy (13).

Although INCS and LTRA have different mechanisms of action, the combination of an LTRA with an INCS may provide additional effects on the improvement of nasal symptoms of AR. Combination therapy is an option which may be offered to patients with AR who do not respond to monotherapy (1, 2). Potentially, this combination of INCS and LTRA (INCS+LTRA) may also be more effective in controlling the symptoms of AR patients with/without asthma. This systematic review aimed to assess the effects of INCS+LTRA vs INCS in monotherapy in relieving rhinoconjunctivitis symptoms of AR.

Materials and methods
Eligibility criteria
This systematic review followed The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)16. Randomized controlled trials (RCTs) studying the effects of INCS+LTRA versus INCS in monotherapy in patients with AR were included. The diagnostic criteria of AR followed the Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines (1). RCTs studying INCSs and LTRAs, at any dose, frequency, and duration were included in the analysis. The selected outcomes were nasal symptoms, ocular symptoms, disease-specific QOL, and adverse events. RCTs published in a language other than English were excluded. RCTs with mixed populations of AR and non-AR were excluded unless the outcomes for patients with AR could be isolated.

Information sources and search strategy
Electronic systematic searches for RCTs were conducted with no publication year, or publication status restrictions. The last search was performed on 19 May 2020. Literature searches were performed using Ovid MEDLINE, Ovid EMBASE, CENTRAL, and Web of Science. References of the included studies were searched for identifying any missing published or unpublished trials. The searched term used was (Leukotriene receptor antagonist OR Leukotriene receptor blocking agent OR antileukotriene OR Montek OR Montelukast OR Singular) AND (Triamcinolone Acetonide OR Nasacort OR Nasonex OR Mometasone Furoate OR Rhinocort OR Budesonide OR Pulmicort OR Flonase OR Dexamethasone OR Betamethasone OR Omna- nis OR Ciclesonide OR Veramyst OR Flunisolide OR Nasalide OR Beclomethasone OR hydrocortisone) AND (allergic rhinitis). Study selection and data collection
Two review authors (KL and VA) independently performed trial selection by title and abstract screening based on predetermined eligibility criteria. The full-text articles of the selected RCTs were reviewed. Two authors (KSe and KL) extracted details of the included studies. When insufficient information or conflicting data were found during the data collection, the corresponding author was approached for further information. Any disagreements over data were resolved by the fifth author (KSn) if necessary. The collected data included: study type, number of participants, mean age, gender, primary outcomes and secondary outcomes. The primary outcomes were nasal symptoms, ocular symptoms, and disease-specific QOL. The secondary outcomes were adverse events. Data of patients with comorbid asthma were extracted separately when possible, for subgroup analysis.

Risk of bias in included studies
The quality of included RCTs was assessed by evaluating the risks of bias as guided by the Cochrane Handbook for Systematic Reviews of Interventions (17). Five domains were assessed: random sequence generation, allocation concealment, blinding of outcome assessment, incomplete outcome data, and selective reporting. The included studies had a low risk of bias when the methods used for each domain were clearly described. When

Figure 1. Flow diagram of study selection for the systematic review and meta-analysis.

Fluticasone OR Dexamethasone OR Betamethasone OR Omnans OR Ciclesonide OR Veramyst OR Flunisolide OR Nasalide OR Beclomethasone OR hydrocortisone AND (allergic rhinitis).
Finally, a total of 5 studies were included for the meta-analysis (19-21,23,24). Characteristics of the included studies are shown in Table 1. A flow chart of the study retrieval and selection is presented in Figure 1.

### Participants

In these 6 studies, there were a total of 358 participants. The mean age was 28.9 years, being 41.6% male. The diagnosis of AR was confirmed by skin tests or serum-specific IgE in 298 patients. Three RCTs studied pediatric and adult patients (19,20,23) while three RCTs studied only adult patients (21,22,24). Two RCTs studied patients with seasonal AR (SAR) (19,24), while two studied perennial AR (PAR), one with persistent disease (21,22). Concerning severity, four RCTs studied moderate to severe AR (19,22-24). One trial included AR patients with comorbid mild asthma, but the data were not reported separately (21). Patients with asthma were excluded from five trials (19,20,22-24).

### Intervention

One RCT used mometasone furoate 200µg per day (22), three used fluticasone propionate 200µg per day (50 µg/actuation, two actuations into each nostril once a day) (19,21,23), one used fluticasone propionate 400µg per day (200 µg into each nostril once a day) (20), and one used budesonide 256µg per day (64 µg into each nostril twice daily) (24). All RCTs used oral montelukast (10mg/day) as the LTRA (19,24). Treatment duration ranged from 2 to 8 weeks.

### Outcomes

**Nasal symptom score.** The nasal symptom was scored using

<table>
<thead>
<tr>
<th>First author</th>
<th>Year</th>
<th>Study Type</th>
<th>Disease phenotype</th>
<th>Patients Age (years old)</th>
<th>Number of patients</th>
<th>LTRA drug</th>
<th>LTRA dose (mg/d)</th>
<th>INCS drug</th>
<th>INCS dose (µg/d)</th>
<th>Duration of treatment (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Di lorenzo</td>
<td>2004</td>
<td>RPCT, DB</td>
<td>Moderate to severe SAR</td>
<td>12-50</td>
<td>100</td>
<td>Montelukast</td>
<td>10</td>
<td>Fluticasone propionate</td>
<td>200</td>
<td>6</td>
</tr>
<tr>
<td>Modgill</td>
<td>2010</td>
<td>RCT</td>
<td>AR</td>
<td>15-55</td>
<td>90</td>
<td>Montelukast</td>
<td>10</td>
<td>Fluticasone propionate</td>
<td>400</td>
<td>4</td>
</tr>
<tr>
<td>Esteitie</td>
<td>2010</td>
<td>RPCT, DB</td>
<td>PAR</td>
<td>18-55</td>
<td>54</td>
<td>Montelukast</td>
<td>10</td>
<td>Fluticasone propionate</td>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td>Tatar</td>
<td>2013</td>
<td>RCT</td>
<td>Moderate to severe persistent AR</td>
<td>17-67</td>
<td>56</td>
<td>Montelukast</td>
<td>10</td>
<td>Mometasone furoate</td>
<td>200</td>
<td>4</td>
</tr>
<tr>
<td>Goh</td>
<td>2014</td>
<td>RPCT, DB</td>
<td>Moderate to severe SAR</td>
<td>&gt;12</td>
<td>128</td>
<td>Montelukast</td>
<td>10</td>
<td>Fluticasone propionate</td>
<td>200</td>
<td>8</td>
</tr>
<tr>
<td>Chen</td>
<td>2019</td>
<td>RCT</td>
<td>Moderate to severe SAR</td>
<td>18-60</td>
<td>41</td>
<td>Montelukast</td>
<td>10</td>
<td>Budesonide</td>
<td>256</td>
<td>2</td>
</tr>
</tbody>
</table>

LTRA, leukotriene receptor antagonist; INCS, intranasal corticosteroid; mg/d, milligram per day; µg/d, microgram per day; RPCT, Randomized placebo-controlled trial; RCT, Randomized controlled trial; DB, Double-blind; SAR, seasonal allergic rhinitis; PAR, perennial rhinitis.
Antileukotriene and intranasal steroid combination

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>INCS+LTRA</th>
<th>INCS</th>
<th>Std. Mean Difference IV, Random, 95% CI</th>
<th>Risk of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Di Lorenzo 2004</td>
<td>-3.01</td>
<td>20</td>
<td>-4.96</td>
<td>D E</td>
</tr>
<tr>
<td>Estelle 2010</td>
<td>-0.21</td>
<td>20</td>
<td>-5.57</td>
<td>D E</td>
</tr>
<tr>
<td>Chen 2019</td>
<td>-5.04</td>
<td>20</td>
<td>-3.8</td>
<td>D E</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>68</td>
<td>67</td>
<td>100.0%</td>
<td>Low risk of bias</td>
</tr>
</tbody>
</table>

Risk of bias legend:
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Incomplete outcome data (attrition bias)
(E) Selective reporting (reporting bias)

Figure 2. Improvement in the composite nasal symptom score: Intranasal corticosteroid plus leukotriene receptor antagonist vs intranasal corticosteroid in monotherapy. Abbreviations: SMD, standardized mean difference; IV, inverse variance; Random, Random effects; CI, confidence interval; df, degrees of freedom; INCS, intranasal corticosteroid; LTRA, leukotriene receptor antagonist.

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>INCS+LTRA</th>
<th>INCS</th>
<th>Std. Mean Difference IV, Random, 95% CI</th>
<th>Risk of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modgil 2010</td>
<td>0.33</td>
<td>28</td>
<td>-1.07</td>
<td>D E</td>
</tr>
<tr>
<td>Goh 2014</td>
<td>-2.75</td>
<td>64</td>
<td>1.81</td>
<td>D E</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>92</td>
<td>94</td>
<td>100.0%</td>
<td>Low risk of bias</td>
</tr>
</tbody>
</table>

Risk of bias legend:
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Incomplete outcome data (attrition bias)
(E) Selective reporting (reporting bias)

Figure 3. Improvement in the total daytime symptom score: Intranasal corticosteroid plus leukotriene receptor antagonist vs Intranasal corticosteroid. Abbreviations: SMD, standardized mean difference; IV: inverse variance, Random: Random effects, CI: confidence interval, df: degrees of freedom, INCS: Intranasal corticosteroid, LTRA: leukotriene receptor antagonist.

Ocular symptom score. The assessed ocular symptoms were tearing, ocular itching, redness, and puffiness. The ocular symptom was scored by a 4-point scale (0 none, 1 mild, 2 moderate, and 3 severe). One RCT assessed composite nasal symptom score (0 cm = no symptoms and 10 cm = most severe and bothersome symptom). The scoring system was not described in one study. Four RCTs assessed composite nasal symptom score. There was no significant statistical difference in the composite nasal symptom score between the INCS+LTRA and INCS in monotherapy (SMD -0.91, 95%CI -2.52 to 0.70, p=0.27, 3 RCTs). An I² of 93% represented substantial heterogeneity of the 3 RCTs. There were no significant differences between the INCS+LTRA and INCS in monotherapy in total daytime symptom score (SMD -1.42, 95%CI -4.70 to 1.87, p=0.40, 2 RCTs) and total nighttime symptom score (SMD -0.55, 95%CI -3.46 to 2.35, p=0.71, 2 RCTs). An I² of 99% represents substantial heterogeneity of the 2 RCTs. The data are displayed in Figures 2-4. The individual nasal symptom score was assessed in five RCTs. One RCT did not report the standard deviation for each individual nasal symptom score and could not be imputed. There were no significant differences between INCS+LTRA and INCS in monotherapy in nasal congestion (SMD -0.98; 95% CI -2.37 to 0.42, p=0.17, 4 RCTs), rhinorrhea (SMD -0.73; 95% CI -2.26 to 0.81, p=0.35, 4 RCTs), itching (SMD -0.73; 95% CI -2.99 to 1.53, p=0.53, 3 RCTs), and sneezing (SMD -0.19; 95% CI -1.76 to 1.38, p=0.81, 4 RCTs). The heterogeneity was substantial for nasal congestion, rhinorrhea, nasal itching, and sneezing (I² of 93%, 94%, 97%, and 96%, respectively). Reduction of nasal symptoms in the subgroup of patients with comorbid asthma could not be assessed as patients with asthma were excluded from most studies.

Disease-specific QOL. Three RCTs assessed disease-specific QOL score. The Rhinoconjunctivitis Quality of Life Questionnaire (RQLQ) was used in two RCTs only. The RQLQ questionnaire comprises 25 questions distributed in 6 domains (activity
limitations, practical problems, nose symptoms, eye symptoms, non-hay fever symptoms, and emotional problems). Each item was rated on a 7-point scale from 0 (no impairment) to 6 (severely impaired). A high score corresponds to the low quality of life. The miniRQLQ comprised 14 questions distributed in five domains (activity limitations, practical problems, nasal symptoms, eye symptoms, and other symptoms) and was used in one trial (22). This trial did not report; however, the standard deviation for the disease-specific QOL score and could not be imputed(22). There was no significant difference between the INCS+LTRA and INCS in monotherapy (SMD -1.65; 95%CI -4.49 to 1.20, p=0.26, 2 RCTs)(21,23). The data are displayed in Figure 5.

Adverse events
The number of patients with adverse events was reported by four RCTs(19,21,22,24). There was no significant difference in adverse events between the INCS+LTRA and INCS in monotherapy (Risk Ratio 1.50, 95%CI 0.54 to 4.18, p=0.44).

Risk of bias in the included studies
From the included studies, 50% and 40% had a low risk of bias in random sequence generation and allocation concealment respectively, while 50% had a high risk of bias in the blinding of outcome assessment. All studies (100%) had a low risk of bias in incomplete outcome data, while 83% had a low risk of bias in selective reporting. Overall, the included studies had selection bias and performance bias, whereas they had low risks in attrition bias and reporting bias (Figure 6).

Discussion
The use of LTRA+INCS combination for treating AR has been a controversial issue in recent years. The results of this study failed to demonstrate the benefits of INCS+LTRA compared to INCS in monotherapy on the improvement in nasal symptoms and disease-specific QOL. In line with our findings, when the olfactory function was assessed by Dalgic et al., LTRA did not add benefits to INCS(26). However, the combination had beneficial effects on extra nasal symptoms. Based on one RCT, the INCS+LTRA combination significantly decreased ocular symptoms compared to the INCS in monotherapy. Goh et al.(23) randomized 128 patients with AR to receive fluticasone propionate nasal spray together with either montelukast tablets or
Antileukotriene and intranasal steroid combination

The combination demonstrated greater effects in both ocular symptom scores and the eye domain of the RQLQ questionnaires. Likewise, previous articles reported that the combination controlled asthmatic symptoms better than the INCS in monotherapy. The INCS+LTRA combination improved lower airway symptoms by the effects on bronchial smooth muscle contraction, vasodilatation, and mucus hypersecretion.

In contrast to the results of the present study, a previous meta-analysis by Feng et al. favoured the INCS+LTRA effects vs INCS in monotherapy. The INCS+LTRA combination improved lower airway symptoms by the effects on bronchial smooth muscle contraction, vasodilatation, and mucus hypersecretion.

In contrast to the results of the present study, a previous meta-analysis by Feng et al. favoured the INCS+LTRA effects vs INCS in monotherapy. The INCS+LTRA combination improved lower airway symptoms by the effects on bronchial smooth muscle contraction, vasodilatation, and mucus hypersecretion.

The limitation of our study was the quality and heterogeneity of the included studies. Most studies had risks of bias in several ways. The common biases were allocation concealment and blinding. Two RCTs included in the meta-analysis had a high risk of bias in blinding of participants and personnel. The Substantial heterogeneity was found for the outcomes of total daytime and nighttime symptoms scores. Thus, the overall effect may be invalid. There was homogeneity among the three randomized controlled trials reporting no difference between the effects of INCS+LTRA vs INCS in monotherapy. It is worth noting that these three RCTs had significant risks of bias and the study, which favored the use of INCS+LTRA had moderate to high quality.

Although the reduction of ocular symptoms was shown, these findings were based on only one trial, being this beneficial effect quite inconclusive. This analysis did not assess the effects in patients with asthma because they were excluded from five trials. Well-conducted randomized controlled trials are required for further evidence-based recommendations.

**Conclusion**

Evidence from five randomized controlled trials in patients with AR did not show benefit of the INCS+LTRA combination when compared to INCS in monotherapy. Nasal symptoms and disease-specific QOL were not different between the two treatments. Although observed, the reduction of ocular symptoms by INCS+LTRA was inconclusive because it was based on a single trial. However, the INCS+LTRA combination was safe and well-tolerated. When INCS fails to improve allergic rhinitis, the INCS+azelastine combination should be a better option.
When oral H1 antihistamine fails, oral H1 antihistamine + LTRA combination might be considered. LTRA should not be used as monotherapy for the treatment of AR.

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Authorship contribution
KSe: study design, search, study selection, data collection, data analysis, drafting the article, and final approval. JM: expert opinion, revising the article, and final approval. KL: search, study selection, data collection, revising the article, and final approval.

Conflict of interest
JM has been a member of the advisory board or speaker bureau or received research grants from Allakos, ALK, AstraZeneca, Genentech, GlaxoSmithKline, Menarini, Mitsubishi-Tanabe, MSD, Mylan-MEDA Pharma, Novartis, Sanofi-Genzyme & Regeneron, UCB, Uriach Group. KSN received Honoraria for speaking at symposia from Merck Sharp & Dohme and Menarini. KSE, KL and VA declare that they have no conflict of interest.

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