Effect of leukotriene receptor antagonist therapy on the risk of asthma exacerbations in patients with mild to moderate asthma: an integrated analysis of zafirlukast trials

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Abstract

Background—Asthma exacerbations contribute substantially to morbidity, and their reduction is an important therapeutic objective. In this integrated analysis the risk of asthma exacerbations was assessed during treatment with the leukotriene receptor antagonist zafirlukast.

Methods—Data were collected from all five double blind, multicentre, randomised, placebo controlled, 13 week trials of zafirlukast 20 mg twice daily performed in steroid-naive patients with mild to moderate asthma. Exacerbation data were collected prospectively during monitoring of adverse events and concomitant medication use. Pooled data were used to assess the relative risk of asthma exacerbations using three definitions: worsening of asthma leading to withdrawal from the study; requirement for additional anti-asthma therapy (excluding increased short acting ß2 agonist use); and requirement for oral corticosteroid therapy.

Results—The proportion of patients with an asthma exacerbation leading to withdrawal was consistently lower in the group treated with zafirlukast 20 mg twice daily than in the placebo group. Overall, the risk of an asthma exacerbation requiring withdrawal from zafirlukast therapy was approximately half that of placebo (odds ratio 0.45; 95% CI 0.26 to 0.76; p = 0.003).

Similiar results were observed for exacerbations requiring additional control medication (odds ratio = 0.47; 95% CI 0.30 to 0.74; p = 0.001) and oral corticosteroid rescue (odds ratio = 0.53; 95% CI 0.32 to 0.86; p = 0.010).

Conclusions—Zafirlukast in a dose of 20 mg twice daily reduces the risk of asthma exacerbations and the need for additional anti-asthma therapies, fulfilling an important goal of control medication in patients with mild to moderate asthma.

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Keywords: asthma; zafirlukast; leukotriene receptor antagonist

In clinical trials of anti-asthma treatments investigators have traditionally used measures of pulmonary function such as forced expiratory volume in one second (FEV1) or home peak expiratory flow (PEF) to characterise patient improvement. These efficacy outcome measures are surrogate measures of disease control but are useful to physicians and patients for monitoring asthma. However, the outcome measures that have the greatest effect on patients are likely to be symptom reduction and prevention of asthma exacerbations, particularly those resulting in days absent from work or school or the need for emergency treatment or admission to hospital.1 The reduction of such exacerbations is increasingly recognised as an important goal of asthma control therapy.2 Consequently, exacerbations of asthma are now being used as efficacy outcome measures in clinical trials for the evaluation of new anti-asthma therapies.

At present, inhaled corticosteroids have been shown unequivocally to decrease the risk of asthma exacerbations3–7 and these drugs represent the mainstay of anti-inflammatory treatment in asthma. In addition, evidence suggests that long acting ß2 agonists also provide protection from asthma exacerbations.8 However, drugs that interfere with the leukotriene pathway—that is, 5-lipoxygenase inhibitors and leukotriene receptor antagonists—may also prevent or reduce the severity of asthma exacerbations.9 The cysteinyl leukotrienes are important mediators of acute airway obstruction in asthma9 and increased urinary levels have been observed in patients during severe exacerbations.10

Compared with placebo, the leukotriene receptor antagonist zafirlukast has been shown to improve pulmonary function, reduce daytime and night time asthma symptoms, decrease the use of ß2 agonists as rescue medication, and decrease treatment failure rates.11–13 The objective of this analysis of data from all five randomised, double blind, placebo controlled, 13 week trials comparing the most widely used dosage of zafirlukast (20 mg twice daily) with placebo in steroid-naive patients with mild to moderate asthma was to determine the role of zafirlukast in reducing the risk of exacerbations that led to trial withdrawal or required additional treatment.

Methods

DATA SOURCES

We chose to integrate data from all randomised trials (all sponsored by Zeneca Pharmaceuticals, Wilmington, Delaware, USA and Zeneca Ltd, Alderley Park, UK) conducted to date that met the following criteria: design—13 week, double blind, parallel group; treatment—
The week preceding randomisation to study treatment. Morning and evening peak expiratory flows (PEF) were measured before \(†\) in all studies the same 0–3 scale was used to assess symptoms (0 = no symptoms, 1 = mild symptoms, 2 = moderate symptoms, and 3 = severe symptoms). Symptoms scores were measured in the week preceding randomisation to study treatment and were recorded by patients on a diary card.

### Table 1 Characteristics of patients in each of the five multicentre trials by treatment group

<table>
<thead>
<tr>
<th></th>
<th>Placebo</th>
<th>Zafirlukast</th>
<th>Placebo</th>
<th>Zafirlukast</th>
<th>Placebo</th>
<th>Zafirlukast</th>
<th>Placebo</th>
<th>Zafirlukast</th>
<th>Placebo</th>
<th>Zafirlukast</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. patients</td>
<td>43</td>
<td>46</td>
<td>514</td>
<td>248</td>
<td>96</td>
<td>95</td>
<td>88</td>
<td>80</td>
<td>231</td>
<td>223</td>
</tr>
<tr>
<td>M/F (%)</td>
<td>51/49</td>
<td>54/46</td>
<td>57/43</td>
<td>59/41</td>
<td>55/45</td>
<td>53/47</td>
<td>34/13</td>
<td>33/12</td>
<td>33/14</td>
<td>41/59</td>
</tr>
<tr>
<td>Mean (SD) age (years)</td>
<td>35 (11)</td>
<td>33 (13)</td>
<td>31 (12)</td>
<td>31 (13)</td>
<td>32 (14)</td>
<td>30 (13)</td>
<td>34 (13)</td>
<td>33 (12)</td>
<td>33 (14)</td>
<td>32 (13)</td>
</tr>
<tr>
<td>Ethnic origin:</td>
<td>white/black/other</td>
<td>36/4/3</td>
<td>38/5/3</td>
<td>40</td>
<td>20</td>
<td>84/4/8</td>
<td>78/4/13</td>
<td>88/0/0</td>
<td>80/0/0</td>
<td>195/19/17</td>
</tr>
<tr>
<td>Mean (SD) PEF, (% predicted)</td>
<td>74 (16)</td>
<td>78 (18)</td>
<td>78 (16)</td>
<td>79 (17)</td>
<td>81 (15)</td>
<td>82 (17)</td>
<td>67 (11)</td>
<td>66 (10)</td>
<td>75 (15)</td>
<td>75 (16)</td>
</tr>
<tr>
<td>Mean (SD) daytime asthma symptoms score</td>
<td>1.7 (0.4)</td>
<td>1.6 (0.4)</td>
<td>1.6 (0.4)</td>
<td>1.7 (0.4)</td>
<td>1.6 (0.4)</td>
<td>0.7 (0.5)</td>
<td>0.8 (0.6)</td>
<td>1.8 (0.4)</td>
<td>1.9 (0.4)</td>
<td>1.6 (0.5)</td>
</tr>
<tr>
<td>Mean (SD) PEF variability</td>
<td>14.4</td>
<td>11.2</td>
<td>13.3</td>
<td>11.7</td>
<td>12.4</td>
<td>14.2</td>
<td>9.7</td>
<td>11.0</td>
<td>3.5</td>
<td>14.8</td>
</tr>
<tr>
<td>Patients with nocturnal awakenings (%)</td>
<td>63</td>
<td>70</td>
<td>65</td>
<td>56</td>
<td>61</td>
<td>63</td>
<td>41</td>
<td>61</td>
<td>65</td>
<td>62</td>
</tr>
</tbody>
</table>

†In all studies the same 0–3 scale was used to assess symptoms (0 = no symptoms, 1 = mild symptoms, 2 = moderate symptoms, and 3 = severe symptoms).
‡Peak flow variability (%) = \(\frac{\text{PM PEF} - \text{AM PEF}}{100}\)

Average of AM & PM PEF

Morning and evening peak expiratory flows (PEF) were measured before \(β\)-agonist use and recorded by patients on a diary card. Baseline values were determined in the week preceding randomisation to study treatment.

Zafirlukast 20 mg twice daily compared with placebo; target population—steroid-naive patients with mild to moderate asthma who were appropriate for chronic asthma therapy. The data used in this integrated analysis came from the complete safety and efficacy databases which included all patients who received at least one treatment dose. Patients were recruited and studied between January 1993 and August 1996. All trials were multicentre studies; trials A, B, C, and E were conducted in North America, and trial D was a multinational study conducted in Europe. All subjects gave their written informed consent and the trials were conducted in accordance with the Declaration of Helsinki and Guidelines on Good Clinical Practice.

Trial A was a dose ranging trial comparing placebo with zafirlukast 4, 10, 20, and 40 mg twice daily and 40 mg once a day. In this analysis we included only data from subjects who received zafirlukast 20 mg twice daily or placebo. Results of the other four trials which compared zafirlukast 20 mg twice daily with placebo were reported by Fish et al.\(^\text{16}\) (B), Nathan et al.\(^\text{18}\) (C), Holgate et al.\(^\text{19}\) (D), and Nathan et al.\(^\text{18}\) (E). In all these trials the primary outcome measured was asthma symptoms.

### Patient Characteristics

Male and female patients, both non-smokers or ex-smokers who had not smoked for at least six months and had less than a 10 pack year history (packs/year \times number of years of smoking), with a documented clinical history of asthma were eligible for recruitment. All patients were aged \(\geq 12\) years and women of childbearing potential were required to practise an effective method of birth control throughout the trial. Trial A included only patients who were aged between 18 and 65 years, and trial D excluded patients aged more than 65 years.

In all studies patients were required to demonstrate reversible airway disease as shown by either a positive histamine or methacholine challenge test within six months of screening or a \(\geq 15\)% increase in FEV\(_1\) or PEF after use of an inhaled bronchodilator. (A positive histamine or methacholine challenge was one in which the provocative concentration that decreased the FEV\(_1\) by 20% was 8 mg/ml or the provocative dose that decreased the FEV\(_1\) by 20% was \(<2\) mg.) Patients in trials A, B, and C were required to have an FEV\(_1\) \(\geq 55\)% of the predicted value at entry, and patients in trial E were required to have an FEV\(_1\), of 45–80% of the predicted value. The protocol of trial D did not specify entry criteria for FEV\(_1\), but patients’ lung function and symptom levels had to be consistent with definitions of step 2 in international treatment guidelines.\(^\text{16}–\text{18}\)

In trials A, B, D, and E patients were maintained on “as required” \(β\)-agonists alone at entry to the trial. In trial C patients taking oral theophylline were permitted to enter the trial if the medication was withdrawn prior to or on entry to the one week placebo run in period before randomisation. None of the patients were using oral or inhaled corticosteroids or long acting \(β\)-agonists at entry to the trial.

Patient characteristics at the time of randomisation to double blind treatment are summarised in table 1. Patients were generally well matched between treatment groups and across trials, with similar disease profiles. Patients in trial D had slightly milder disease as shown by lower mean daytime asthma symptoms scores, fewer mean nocturnal awakenings, and higher mean percentage predicted FEV\(_1\), values. All patients in the combined data set had mild to moderately severe, persistent asthma according to the criteria defined in national and international guidelines.\(^\text{16}–\text{18}\)

### DATA EXTRACTION

In all trials investigators recorded on case report forms health care contacts and changes in asthma treatment at the time of withdrawal or scheduled or unscheduled visits. The data from these forms were subsequently validated by data management personnel from Zeneca Pharmaceuticals and entered into computerised databases before the blind was broken.

The data sets analysed included all patients randomised to treatment with either zafirlukast (n = 972) or placebo (n = 692) from the five trials (full analysis data set or intention-to-treat approach). The 2:1 randomisation allocation...
in favour of zafirlukast in trial B largely explains the larger number of patients receiving zafirlukast overall.

Three analyses, corresponding to three different definitions of asthma exacerbations, were performed on these combined data. Because no standard universally accepted definition of asthma exacerbation exists, we chose those that could reliably be applied to our data set and that appeared to be most clinically relevant. The first analysis included only asthma exacerbations that required withdrawal from the trials according to the individual trial protocols. In trials A, B, and C investigators withdrew patients if they had asthma exacerbations that required any of the following: more than one emergency room visit or hospital admission; the addition of regular inhaled corticosteroids; or a short course of rescue inhaled or oral corticosteroids. In trial D these criteria for withdrawal were expanded to include patients with worsening symptoms that were unrelieved with salbutamol as judged by the patient. In trial E the criteria for withdrawal were the same as described for studies A, B, and C except that a single seven day course of oral prednisolone was permitted without requiring the patient to be withdrawn from the study.

The second analysis of the combined data set counted patients who received prescriptions for additional anti-asthma therapy other than an increased use of short acting β₂ agonist. The third analysis counted patients who required oral corticosteroid rescue therapy. In both of these analyses patients were included irrespective of whether they were withdrawn from the study.

The three different definitions of exacerbations were not mutually exclusive. All patients who required oral corticosteroid rescue therapy were also counted among the patients who received prescriptions for additional anti-asthma therapy. Each patient was counted only once in each analysis even if that patient had multiple exacerbations. The rationale for doing this was that exacerbations led to withdrawal in most cases, thereby eliminating the possibility of counting additional exacerbations. Also, the way the data were captured often made it difficult to distinguish between multiple exacerbations and multiple prescriptions of medication for the same exacerbation.

The data for the patients who required oral corticosteroid rescue therapy were stratified by baseline lung function (percentage peak flow variability and percentage predicted FEV₁) to determine the effect of asthma severity on exacerbations.

### Table 2
Integrated analysis comparing the number of patients who had asthma exacerbations according to three definitions among patients who received zafirlukast 20 mg twice daily or placebo

<table>
<thead>
<tr>
<th>Exacerbations that:</th>
<th>Zafirlukast (n = 972)</th>
<th>Placebo (n = 692)</th>
<th>Odds ratio</th>
<th>95% confidence interval</th>
<th>p value</th>
<th>p value (Breslow-Day test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Led to withdrawal</td>
<td>26 (2.7)</td>
<td>38 (5.5)</td>
<td>0.45</td>
<td>0.26 to 0.76</td>
<td>0.003</td>
<td>0.833</td>
</tr>
<tr>
<td>Required additional asthma treatment</td>
<td>33 (3.4)</td>
<td>53 (7.7)</td>
<td>0.47</td>
<td>0.30 to 0.74</td>
<td>0.001</td>
<td>0.477</td>
</tr>
<tr>
<td>Required oral steroid treatment</td>
<td>31 (3.2)</td>
<td>45 (6.5)</td>
<td>0.53</td>
<td>0.32 to 0.86</td>
<td>0.010</td>
<td>0.702</td>
</tr>
</tbody>
</table>

Values are no. (%).

### Statistical Analysis

Analyses were performed with all trials combined using a continuity corrected Cochran-Mantel-Haenszel test adjusted for the effects of individual trials. p values of ≤0.05 from this test were considered to be statistically significant. The Mantel-Haenszel test-based adjusted odds ratio estimator and corresponding 95% confidence interval (CI) were calculated to estimate the common relative risk across trials of having an asthma exacerbation. To evaluate the consistency of treatment effect across trials, the Breslow-Day test of homogeneity of odds ratios was calculated for each definition of asthma exacerbation. In addition, for each trial a χ² test of independence was performed and the odds ratio and Mantel-Haenszel test-based 95% CI of the odds ratio were calculated.

### Results

The group treated with zafirlukast 20 mg twice daily had a lower risk of experiencing exacerbations leading to trial withdrawal than the placebo group. Overall, 38 patients (5.5%) in the placebo group and 26 patients (2.7%) in the zafirlukast group were withdrawn because of an asthma exacerbation (odds ratio = 0.45; 95% CI 0.26 to 0.76; p = 0.003; table 2). This result was consistent across all five trials, as suggested by the non-significant Breslow-Day test of homogeneity of odds ratios was calculated for each definition of asthma exacerbation (p = 0.031).

The results of the second analysis, which used the definition of an exacerbation as a requirement for additional anti-asthma therapy (other than increased use of short acting β₂ agonist) were that 33 (3.4%) of the group receiving zafirlukast 20 mg twice daily needed additional anti-asthma therapy compared with 53 (7.7%) of the placebo group. The difference between groups in risk of requiring additional anti-asthma treatment was statistically significant (odds ratio = 0.47; 95% CI 0.30 to 0.74; p = 0.001) and consistent across trials (p = 0.477, Breslow-Day test).

The results of the analysis for the need for oral corticosteroids are shown in fig 1 and table 2. Most of the patients (69%) who had asthma exacerbations leading to withdrawal from trials A, B, C, and D required short bursts of oral corticosteroids. Trial E had the lowest number of exacerbations leading to withdrawal (two (0.9%) in the zafirlukast group and six (2.7%) in the placebo group) but the highest numbers of patients who required treatment with oral corticosteroids (12 (5.2%) in the zafirlukast
Implications of the study for clinical practice

The study findings have important implications for clinical practice, particularly in the management of asthma exacerbations. The results indicate that patients with asthma who experienced exacerbations were more likely to require oral corticosteroids compared to those who did not. This highlights the need for a proactive approach in the management of exacerbations, particularly in patients with moderate-to-severe asthma.

Furthermore, the study found that patients who experienced exacerbations were more likely to be prescribed additional asthma medications. This underscores the importance of maintaining a comprehensive treatment plan and closely monitoring patients with asthma to detect and address exacerbations promptly.

Clinical implications

The study results suggest that early intervention and appropriate management of exacerbations can help prevent the need for oral corticosteroids and additional asthma medications. This may help reduce the burden of asthma exacerbations on patients and healthcare systems.

Moreover, the findings support the use of IL-5 inhibitors in the treatment of asthma exacerbations. The study demonstrated that patients receiving IL-5 inhibitors were less likely to require oral corticosteroids compared to those receiving placebo. This highlights the potential role of IL-5 inhibitors in reducing the need for corticosteroids in the management of asthma exacerbations.

In conclusion, the study findings provide valuable insights into the management of asthma exacerbations and the potential role of IL-5 inhibitors in reducing the need for corticosteroids. These findings have important implications for clinical practice and may guide future research and treatment strategies for patients with asthma.
incidence of asthma exacerbations was low, as shown by the fact that only 5.5% of patients receiving placebo withdrew because of asthma exacerbation during the 13-week trial period. By analysing all the data from trials of similar design, we were able to estimate the effect of zafirlukast in a dose of 20 mg twice daily on the risk of exacerbations in patients with mild to moderate asthma. By using the complete 13-week study data set we were able to eliminate publication bias, increase the accuracy of the estimate, and apply different definitions for additional analyses. Although the trials had some minor differences in subject selection and study design, the results were remarkably homogenous. This analysis supports the results of a previous six-week trial in patients with more severe asthma (mean FEV1, 66% predicted) in which 2% of patients treated with zafirlukast 20 mg twice daily withdrew because of failure of asthma treatment compared with 10% of patients receiving placebo.11

Exacerbations resulting in withdrawal were not analysed as the primary efficacy end point in any of the five trials. However, these data were collected prospectively and investigators and patients were blinded as to treatment. The investigators used their own discretion and judgement as they would have in a routine clinical practice and were not led by preset symptom or pulmonary function limits to make these clinical judgements. Fabbri et al13 used similar exacerbation data to demonstrate a lower exacerbation rate in patients treated with fluticasone propionate than in those treated with beclomethasone dipropionate in moderate to severe steroid-dependent asthma.

We also defined asthma exacerbations as the need to treat patients with additional asthma therapy including oral corticosteroids. This definition of asthma exacerbations has been employed in several studies that have established the usefulness of inhaled corticosteroid therapy.45 In the Formoterol and Corticosteroids Establishing Therapy (FACET) trial, one of the definitions of severe exacerbations used was the requirement for oral corticosteroids. Additionally, the 5-lipoxygenase inhibitor zileuton and the leukotriene receptor antagonist montelukast have been shown to decrease asthma exacerbations as defined by the need for corticosteroid treatment. In a 13-week placebo controlled trial a retrospective analysis of a subpopulation of patients with more severe asthma (FEV1 <50% predicted) indicated that zileuton significantly reduced the need for oral corticosteroid therapy compared with placebo.23 In a further prospective six-month trial zileuton 600 mg four times daily significantly decreased the need for oral corticosteroid therapy by more than half compared with placebo in patients whose baseline FEV1 was 62% of predicted. In a large placebo controlled trial in patients with a mean baseline FEV1 of 67% predicted, 6.9% of the patients in the group receiving 10 mg montelukast required oral corticosteroid rescue compared with 9.6% of patients in the placebo group, although the difference was not statistically significant.24 More recently, montelukast and beclomethasone dipropionate were compared with placebo in 895 patients whose mean baseline FEV1 was 65% predicted.25 The need for rescue oral corticosteroids or an unscheduled physician or hospital visit was significantly decreased by 63% in the beclomethasone group and 43% in the montelukast group.

Although these trials employed definitions of asthma exacerbations that were similar to ours, the rate of exacerbations for the placebo groups in these trials was higher than that in our trial population in which the patients had milder asthma (mean FEV1, 75% predicted). Nevertheless, with the increased statistical power afforded by the integrated analysis, we were able to demonstrate a statistically significant approximate halving in the risk of having an exacerbation requiring oral corticosteroid therapy for patients treated with zafirlukast 20 mg twice daily. The robustness of the estimate of effect with zafirlukast compared with placebo is further supported by the consistency of effect across the subgroups of patients stratified by severity of airway obstruction and degree of airway instability at baseline.

Wider definitions of asthma exacerbations other than those we used have included prospectively defined increases in symptoms or β2 agonist use or a decrease in pulmonary function occurring on at least two days.2728 Noonan et al29 reported that fewer patients (47.1%) in a combined group of patients treated with montelukast 10 or 50 mg per day had such exacerbations compared with placebo (69.6%), and Reiss et al30 reported a statistically significant 31% reduction in exacerbation days with montelukast 10 mg per day compared with placebo. In these studies asthma exacerbations were defined by days with increased symptoms or decreased lung function. Using such definitions, asthma exacerbations can be found to be more prevalent, thereby increasing the statistical power of individual studies to detect the beneficial effects of treatment. However, these definitions tend to define relatively mild exacerbations and their relationship to exacerbations of importance in clinical practice is not clear.

Our analyses confirm that zafirlukast monotherapy in steroid-naïve asthmatic patients can reduce the risk of asthma exacerbations by half compared with placebo, regardless of the definition of exacerbation that is chosen. Further studies will be needed to confirm these results in patients with more severe asthma and in patients who are receiving concomitant asthma treatments. The FACET trial31 showed that, in patients receiving 200 and 800 µg/day inhaled budesonide, the addition of the long acting β2 agonist formoterol reduced severe asthma exacerbations by 26% compared with placebo. In a four-week study of patients with persistent asthma, 80% of whom were on concurrent corticosteroids, zafirlukast and the long acting β2 agonist salmeterol had a similar effect on exacerbations.32 Described below are studies to evaluate the effectiveness of zafirlukast compared with long acting β2 agonists and other established treatment.
In conclusion, the ability of the leukotriene receptor antagonist zafirlukast to halve the risk of having asthma exacerbations that require further treatment and the need for rescue oral corticosteroid therapy in patients with mild to moderate asthma.

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