Effect of the 5-lipoxygenase inhibitor ZD2138 on aspirin-induced asthma

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Abstract

Background — The cysteinyl leukotrienes may play a central part in the mechanisms of aspirin-sensitive asthma. Previous work has shown that individuals with aspirin-sensitive asthma have high basal urinary LTE₄ levels which increase further upon aspirin ingestion, and that sulphinodipetide leukotriene receptor antagonists attenuate aspirin-induced airflow obstruction. If the cysteinyl leukotrienes cause aspirin-induced asthmatic reactions, inhibition of the 5-lipoxygenase pathway should prevent aspirin-induced bronchospasm. This hypothesis has been tested with ZD2138, a specific non-redox 5-lipoxygenase inhibitor.

Methods — Seven subjects (four men) with aspirin-sensitive asthma with baseline FEV₁ values >67% were studied. ZD2138 (350 mg) or placebo was given on two separate occasions two weeks apart in a randomised double blind fashion. A single dose of aspirin was administered four hours after dosing and FEV₁ was measured for six hours. Inhibition of the 5-lipoxygenase pathway by ZD2138 was assessed by measurements of urinary LTE₄ levels and ex vivo calcium ionophore stimulated LTβ generation in whole blood, before administration of drug or placebo and at regular time intervals after dosing and aspirin administration.

Results — ZD2138 protected against the aspirin-induced reduction in FEV₁, with a 20:3 (4-9)% fall in FEV₁, following placebo compared with 4:9 (2-9)% following ZD2138. This was associated with 72% inhibition of ex vivo LTβ generation in whole blood at 12 hours and a 74% inhibition of the rise in urinary LTE₄ excretion at six hours after aspirin ingestion.

Conclusions — In aspirin-sensitive asthma the 5-lipoxygenase inhibitor ZD2138 inhibits the fall in FEV₁ induced by aspirin and this is associated with substantial inhibition of 5-lipoxygenase.

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Asthmatic patients with aspirin-sensitive asthma¹ are a readily identifiable group of subjects who develop bronchospasm on ingestion of aspirin or non-steroidal anti-inflammatory drugs. Other aspirin-induced symptoms in these subjects include rhinorrhea, nasal and ocular congestion, generalised flushing, nausea, vomiting, headache, and abdominal cramps. Characteristically these subjects have persistent nasal polyposis, rhinorrhea, nasal congestion, anosmia with loss of taste, and frequent exacerbations of asthma.²-⁵

Arachidonic acid released from cell membrane phospholipids by phospholipase A₂ may be further metabolised by the cyclooxygenase pathway to prostaglandins and thromboxane A₂ or by the 5-lipoxygenase pathway to leukotrienes.⁶ The initial leukotriene formed by the action of 5-lipoxygenase is LTA₄, which is then further metabolised by an epoxide hydrolase to LTB₄, or by a glutathione S-transferase termed LTC₄ synthase⁷ to LTC₄, which is further cleaved to LTD₄ by gamma-glutamyl transpeptidase and to LTE₄ by a dipeptidase. The cysteinyl leukotrienes LTC₄, LTD₄, and LTE₄ are potent spasmsogens for airway smooth muscle⁸ and comprise the activity previously recognised as slow reacting substance of anaphylaxis.⁹

The mechanism of aspirin-sensitive asthma remains unresolved, but it is known that the ability of drugs to cause symptoms in aspirin-sensitive asthma is related to their potency as cyclooxygenase inhibitors.¹⁰ It has been proposed that blockade of cyclooxygenase activity by these agents leads to diversion of arachidonic acid metabolism from the cyclooxygenase to the 5-lipoxygenase pathway with consequent increased leukotriene production.¹¹ The evidence for the involvement of the cysteinyl leukotrienes in aspirin-sensitive asthma is compelling. Subjects with aspirin-sensitive asthma have six times higher basal levels of urinary LTE₄ than aspirin-tolerant asthmatic and non-asthmatic subjects.¹² Furthermore, aspirin challenge of subjects with aspirin-sensitive asthma, which leads to bronchoconstriction, is accompanied by a mean fourfold increase in urinary LTE₄ excretion.¹² No clinical symptoms or increase in urinary LTE₄ levels are detected in non-aspirin-sensitive asthmatic individuals following aspirin ingestion. Additionally, there is increased target organ sensitivity to the bronchospastic effects of inhaled LTE₄ in subjects with aspirin-sensitive asthma compared with aspirin-tolerant asthmatic subjects.¹³ Previous studies have shown the efficacy of cysteinyl leukotriene receptor antagonists in the mechanisms of aspirin-sensitive asthma.¹⁴⁻¹⁵ If leukotrienes are critical in the asthmatic response provoked by aspirin, one might expect an inhibitor of 5-lipoxygenase to block aspirin-sensitive asthma. We have tested this hypothesis with ZD2138, a novel non-redox lipoxygenase inhibitor¹⁶ which is well tolerated and, at single oral doses of 350 mg or greater, inhibits ex vivo LTβ synthesis in whole blood for 24 hours.¹⁷

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Methods

STUDENTS

Seven non-smoking subjects (three women) of mean age 42 (range 35–52) years with aspirin-sensitive asthma were studied (table 1). Their resulting mean (SE) forced expiratory volume in one second (FEV₁) was 2.57 (0.17) (mean predicted 86%; range 67–105%). All subjects also suffered with symptoms of rhinosinusitis comprising nasal congestion, rhinorrhea, and varying degrees of dysosmia and loss of taste. The study was approved by the Guy’s Hospital ethics committee and written informed consent was obtained from each subject.

STUDY PROTOCOL

Subjects were screened for aspirin sensitivity if they had a history of worsening asthma on aspirin ingestion. They were studied on three days, each separated by two weeks. On day 1 a medical history was taken and the subjects underwent general physical examination with an ECG. Blood was taken for a full blood count, clotting studies, estimation of electrolytes and urea, and liver function tests. Urine was examined by microscopy and tested for glucose, protein, and blood. Oral aspirin challenge was then performed with incremental doses of aspirin at two-hourly intervals, starting with 30 mg. The dose of aspirin resulting in a 20% or greater fall in FEV₁ within two hours of ingestion was considered the threshold dose and used on days 2 and 3.

On days 2 and 3 350 mg ZD2138 (Zeneca Pharmaceuticals, Macclesfield, Cheshire, UK) or matching placebo was given after an overnight fast in a randomised, double blind fashion. Four hours later aspirin challenge was performed with the threshold dose as determined on day 1. Continuous ambulatory ECG was monitored on days 2 and 3 for 24 hours. Urine was collected before drug or placebo administration and then immediately before and three, six, and nine hours after aspirin challenge. Blood for determination of ex vivo LTβ₄ generation was taken before and after (pre-aspirin), 12, and 24 hours after drug or placebo administration.

SPIROMETRY AND ASPIRIN CHALLENGE

Two recordings of FEV₁ were made with a dry wedge bellows spirometer (Vitalograph Ltd, Buckingham, UK) at each time point and the highest value was used. Aspirin was prepared in gelatin capsules of 10, 30, and 100 mg by the Guy’s Hospital pharmacy. On study day 1 screening for aspirin sensitivity by aspirin challenge was performed. The starting dose of aspirin was 30 mg, after which measurements of FEV₁ were made at 15 minute intervals for two hours. The challenge was stopped if the FEV₁ had fallen by 20% or more within this time. If the fall was less than 20% and the subject was within 10% of baseline FEV₁, further incremental doses of aspirin were given in the order 60, 100, 300, and 600 mg at two-hourly intervals. A fall in FEV₁ of between 10% and 20% was allowed to return to within 10% of baseline before the next dose was administered. The dose that elicited a fall in FEV₁ of 20% or more was considered the threshold dose. On study days 2 and 3 the threshold dose of aspirin was administered four hours after dosing with placebo or ZD2138 and FEV₁ was measured at 15 minute intervals for two hours and then hourly until six hours after aspirin administration. All subjects were asked to report any new symptoms or change in symptoms after aspirin ingestion from the baseline period and these were recorded. Antihistamines were discontinued for 48 hours, inhaled and nasal corticosteroids for 24 hours, and salbutamol for at least eight hours before each study day until 24 hours after aspirin challenge.

MEASUREMENT OF URINARY LTE₄

The free radical scavenger 4-hydroxy-2,2,6,6-tetramethylpiperidinoxy free radical (4-hydroxy-TEMPO; Sigma Chemical Company, Poole, Dorset, UK) was added to each urine sample immediately after collection to a final concentration of 1 mmol/l, the samples were adjusted to pH 9 with NaOH to stabilise endogenous leukotriene metabolites and stored at −70°C until analysed. Urinary LTE₄ levels were measured as described previously.18 The stored urine samples were thawed and 50 μl of a solution containing [H]LTE₄ (125-5 Ci/mmol; NEN, DuPont, Boston, USA) was added to 10 ml urine to give 4000 disintegrations per minute. After adding 250 μl glacial acetic acid to bring the pH to 3.5–3.8 the 10 ml sample was loaded onto a 10 μm precolumn (Ultrasil ODS, 3.4 mm × 4.5 cm, Beckman, USA) to wash off polar metabolites with a phosphate buffer (0.1% NaH₂PO₄, pH 3.8) for eight minutes and then for 12 minutes with methanol:phosphate buffer in the proportions 50:50 (v/v). The sample was then retrogradely eluted onto a reversed phase analytical column (Ultrasil ODS 4.5 mm × 25 cm, Altex) that had been equilibrated in 62% methanol:37.8% water:0.1% acetic acid:0.1% EDTA (v:v:v:v) at pH 5.6 at a flow rate of 1 ml/min. One minute fractions were collected and the fraction containing peak radioactivity corresponding to the internal standard was identified by counting 250 μl of the eluent in a β liquid scintillation counter (Tricarb 1900CA, Packard Instrument Co, USA). The remaining 750 μl of those fractions containing [H]LTE₄ and the two fractions eluted before and after the peak were dried under vacuum and resuspended in 250 μl of

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**Table 1** Baseline FEV₁, values, medication, and threshold dose of aspirin in the seven subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years)</th>
<th>Sex</th>
<th>FEV₁ (litres)</th>
<th>% predicted FEV₁</th>
<th>Drugs</th>
<th>Aspirin dose (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37</td>
<td>M</td>
<td>2.46</td>
<td>67</td>
<td>S, B</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>44</td>
<td>F</td>
<td>2.29</td>
<td>85</td>
<td>S</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>M</td>
<td>3.40</td>
<td>91</td>
<td>S, B</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>F</td>
<td>2.24</td>
<td>89</td>
<td>S, B, nB</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
<td>M</td>
<td>3.04</td>
<td>82</td>
<td>S, B, nB</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>46</td>
<td>M</td>
<td>2.28</td>
<td>81</td>
<td>Bu, nB, T</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
<td>F</td>
<td>2.29</td>
<td>105</td>
<td>Bu, Tn</td>
<td>60</td>
</tr>
</tbody>
</table>

S = salbutamol; B = beclomethasone dipropionate; Bu = budesonide; T = terfenadine; Tn = terbutaline; nB = nasal beclomethasone; nF = nasal fluticasone.
Effect of ZD2138 as aspirin-induced asthma

10 mmol/l Tris HCl buffer (pH 7.4). The concentration of immunoreactive LTE₄ was assessed by radioimmunoassay as described previously. Urinary creatinine concentrations were measured (Mira Analyser, Hoffman Roche, Welwyn) by the kinetic picrate method, without deproteinisation. LTE₄ concentrations were expressed as pg/mg creatinine and were calculated from measured immunoreactivity minus background, corrected for recovery and dilution.

MEASUREMENT OF EX VIVO LTB₄
The ability of ZD2138 to inhibit 5-lipoxygenase was also assessed by measurement of calcium ionophore-stimulated ex vivo LTB₄ production in whole blood. Blood was collected into heparinised tubes and calcium ionophore (A23187) added to 500 µl whole blood in triplicate to a final concentration of 2.5 µmol/l. The blood was incubated for 20 minutes at 37°C, centrifuged at 3600 rpm for one minute, and the supernatant stored at −20°C. LTB₄ was assayed subsequently by radioimmunoassay, as previously described.

DATA ANALYSIS
The area under the FEV₁-time curve following administration of placebo or ZD2138 was calculated for the four hours before aspirin challenge to assess bronchodilatation and for the six hours after aspirin challenge and analysed non-parametrically by the Wilcoxon signed rank test. Using linear regression analysis, the percentage inhibition of urinary LTE₄ was correlated with the degree of protection by ZD2138 against a fall in FEV₁ for each of the periods −4, 0, 0−2, and 2−6 hours after aspirin ingestion. Baseline FEV₁ and urinary LTE₄ values were also correlated with the degree of bronchodilatation in each individual using linear regression analysis. The urinary LTE₄ values were expressed as pg/mg creatinine and the area under the urinary LTE₄-time curve for the drug and placebo days were also compared using the Wilcoxon signed rank test. Data for LTB₄ values were only available for five of the seven subjects because of technical difficulties with the other samples. All data points are expressed as mean (SE).

RESULTS
SUBJECTS
On the screening day all subjects experienced symptoms of wheeze with aspirin ingestion and, in addition, subjects 1, 2, 3, 6, and 7 experienced rhinorrhoea and nasal congestion. Table 2 describes the symptoms experienced by the subjects on the study days. In all subjects ZD2138 premedication reduced aspirin-induced symptoms.

AIRWAY RESPONSES
The resting FEV₁ before drug administration was significantly lower on the ZD2138 day (2.36) than on the placebo day (2.71; p < 0.05). Figure 1 shows the mean change in FEV₁ for four hours after administration of placebo or ZD2138. FEV₁ rose by 7 (2.3) percentage after ZD2138 compared with a fall of 4 (3.9) percentage after placebo (p < 0.05). The mean FEV₁ at four hours after drug/placebo administration and immediately before aspirin challenge was 2.43 (0.16) after ZD2138 and 2.57 (0.17) after placebo (p > 0.05). There was no correlation between the degree of bronchodilatation and baseline urinary LTE₄, baseline urinary LTB₄, or asthma medication.

There was overall protection by ZD2138 of the fall in FEV₁ induced by aspirin challenge (p = 0.05) as shown in fig 2. On the placebo day

Table 2 Symptoms related to aspirin ingestion after premedication with placebo or ZD2138

<table>
<thead>
<tr>
<th>Subject</th>
<th>Placebo day</th>
<th>ZD2138 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rhinorrhoea, conjunctival streaming, wheeze</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>Wheeze, sneezing</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>Rhinorrhoea, epigastric discomfort, wheeze</td>
<td>Nasal tickle</td>
</tr>
<tr>
<td>4</td>
<td>Nausea, vomiting, headache, wheeze</td>
<td>Nausea, headache</td>
</tr>
<tr>
<td>5</td>
<td>Wheeze</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>Nasal congestion, severe fatigue, nausea, chest pain, wheeze</td>
<td>Rhinorrhoea, conjunctival streaming, tiredness</td>
</tr>
<tr>
<td>7</td>
<td>Wheeze, rhinorrhoea, sneezing, headache</td>
<td>—</td>
</tr>
</tbody>
</table>

Figure 1 Percentage change in FEV₁, for the four hours after administration of ZD2138 (●) or placebo (○), and before aspirin challenge.

Figure 2 Mean (SE) percentage change in FEV₁, for six hours after aspirin challenge. ZD2138 (●) or placebo (○) was administered four hours before aspirin challenge.
ther was a mean maximal fall in FEV₁ of 20-3 (4-9)% six hours after administration of aspirin compared with 4-9 (2-9)% on the ZD2138 day. Individual data are shown in fig 3. In subjects 3 and 5 there was complete inhibition and in subjects 1, 2, and 7 there was partial protection of the aspirin-induced asthmatic reaction. In subject 4 there was no inhibitory effect of the 5-lipoxygenase inhibitor on aspirin-provoked bronchoconstriction.

The effects of ZD2138 on aspirin-induced responses are similarly apparent if the maximal falls in FEV₁ in the first two hours and for the 2-6 hour period are analysed. In the first two hours five of the seven individuals clearly showed attenuation of the aspirin-induced response by active drug. Subject 4 could not be evaluated during the first two hours because she did not have a significant fall in FEV₁. Similarly, for the 2-6 hour period five of the seven individuals showed a response (table 3).

There was no significant correlation between inhibition of urinary LTEX levels and protection by ZD2138 against a fall in FEV₁ induced by aspirin for the periods –4–0 hours (r = 0-37; p < 0-5), 0–2 hours (r = 0-43; p < 0-5), and 2–6 hours (r = 0-3; p = 0-5) after aspirin ingestion.

**INHIBITION OF EX VIVO GENERATION OF LTB₄**

Figure 4 shows the mean ionophore-induced generation of LTB₄ from whole blood after administration of placebo and ZD2138. The baseline LTB₄ levels were 102-4 (30) µg/ml and 97-1 (26) µg/ml on the ZD2138 and placebo days, respectively. There was substantial inhibition of ex vivo generation of whole blood LTB₄; compared with placebo there was an average 57% inhibition at four hours, 72% inhibition at 12 hours, and 76% at 24 hours after dosing with ZD2138.

**URINARY LTEX**

There was no significant difference between baseline urinary LTE₄ levels on the two days (fig 5). On the placebo day urinary LTE₄ levels did not change significantly from the baseline value of 391 (72) pg/mg creatinine to 319 (64) pg/mg creatinine at four hours after placebo administration immediately before aspirin challenge (p < 0-05). LTE₄ excretion increased to

806 (369) pg/mg creatinine at three hours, 1853 (986) pg/mg creatinine at six hours, and 1743 (482) pg/mg creatinine at nine hours after aspirin challenge. After administration of ZD2138 there was a fall in urinary LTE₄ levels in all seven subjects from a baseline value of 402 (100) pg/mg creatinine to 180 (47) pg/mg creatinine immediately before aspirin challenge (p < 0-05). The urinary LTE₄ concentration was 275 (181) pg/mg creatinine at three hours, 487 (405) pg/mg creatinine at six hours, and 713 (573) pg/mg creatinine at nine hours after aspirin challenge. Compared with placebo there was 43% inhibition at four hours, 70% at seven hours, 74% at 10 hours, and 59% at 13 hours after dosing with ZD2138. Significantly less urinary LTE₄ excretion was seen after ZD2138 than after administration of placebo (p < 0-05).

ZD2138 was well tolerated and no adverse events attributed to the drug occurred in the study. All seven subjects completed the study.

**Discussion**

The ability of ZD2138 to modulate aspirin-induced asthma has been investigated in seven asthmatic subjects with aspirin sensitivity. ZD2138 is a novel non-redox 5-lipoxygenase inhibitor which is derived from a unique enantiomeric selective series. It is well tolerated and at single oral doses of 350 mg or more inhibits leukotriene synthesis for 24 hours. The drug was given to fasted subjects to standardize bioavailability. The study was designed so that aspirin provocation was undertaken four hours after drug administration when the plasma level of the drug is anticipated to be maximal. Changes in pulmonary function were measured using FEV₁, and the effectiveness of 5-lipoxygenase inhibition was assessed by measuring LTB₄ generation of calcium ionophore-activated whole blood leucocytes and excretion of immunoreactive LTE₄ into the urine.

We have shown that 5-lipoxygenase inhibition by ZD2138 leads to significant bronchodilatation and protection against the fall in FEV₁ induced by oral aspirin challenge in individuals with aspirin-sensitive asthma. In addition, each patient experienced significantly fewer naso-ocular and/or systemic symptoms in response to aspirin after dosing with ZD2138 compared with placebo. The reduction in systemic symptoms was observed even in the individual who showed no amelioration of the decrement in FEV₁ following aspirin ingestion after pretreatment with the active drug (subject 4).

The heterogeneity of FEV₁ responses to the inhibitory effects of antileukotriene drugs has been reported previously. This may reflect heterogeneity of mechanisms for aspirin-sensitive asthma, inadequate 5-lipoxygenase inhibition in some individuals, or involvement of other mediators in the bronchoconstriction produced by aspirin-sensitive asthma. In this regard, naso-ocular symptoms induced by either oral aspirin or inhaled lysine-aspirin are associated with histamine release into nasal lavage fluid. Bosco et al recently reported that histamine and trypase release in venous blood...
Figure 3  Individual graphs for all seven subjects demonstrating the percentage change in FEV₁ for six hours following aspirin challenge. ZD2138 (●) or placebo (○) was administered four hours before aspirin challenge.
samples occurred in three out of four aspirin-sensitive asthmatic subjects following aspirin challenge. These three subjects experienced bronchospasm which was accompanied by gastrointestinal and/or skin reactions. There was no increase in tryptase in the remaining patients who developed bronchospasm but did not experience extrapulmonary symptoms.  

In all subjects ZD2138 inhibited the production of LTB4 by whole blood leucocytes stimulated by calcium ionophore, and this inhibitory activity was present for 24 hours. There was a significant rise in urinary LTE4 excretion in all patients following aspirin ingestion on the placebo day. ZD2138 completely attenuated the rise in urinary LTE4 excretion in all but one subject (subject 6) in whom no difference was seen between the two study days. Thus, there may have been incomplete attenuation of 5-lipoxygenase, accounting for the relative ineffectiveness of the drug in attenuating the pulmonary response to aspirin-sensitive asthma in this individual. Ex vivo LTB4 generation was inhibited by 51%, 38%, and 68% at four, 12, and 24 hours in this individual, however, thereby emphasising possible discordance in the different assays for demonstrating in vivo 5-lipoxygenase inhibition and their relevance to clinical efficacy. In subject 4 there was a substantial increase in urinary LTE4 levels following ingestion of aspirin on the placebo day which was completely inhibited by ZD2138. These observations suggest that the lack of response to ZD2138 in this subject was unlikely to be due to inadequate 5-lipoxygenase inhibition. The possibility that the drug did not reach adequate concentrations locally in the airways cannot be excluded.

The increase in airway calibre following administration of ZD2138 is compatible with the reported effects of another 5-lipoxygenase inhibitor, Zileuton, and leukotriene antagonists, on increasing airway calibre in asthmatic subjects. However, the results of the present study are confounded by the fact that the baseline FEV1 before drug administration was significantly lower than that on the placebo day. The data may therefore be a statistical artefact and simply represent a regression towards the mean. Further studies are needed to define whether there is any significant effect of the active drug on the calibre of resting airways. In a previous study of the effects of ZD2138 on allergen challenge, drug administration did not increase baseline FEV1 values. The asthmatic subjects in that study, however, had milder asthma and their resting FEV1 was almost normal.

The time-dependent decreases in FEV1 following aspirin ingestion on the placebo day in this study were more prolonged than those reported previously. A notable difference between the present study and the earlier reports is that aspirin was administered just before food ingestion in the present investigation. It is therefore possible that food delayed aspirin absorption and the subsequent decrease in FEV1. Future studies should consider using inhaled lysine-aspirin challenge to provoke asthma in aspirin-sensitive individuals to avoid interactions with food.

The mechanism of aspirin-sensitive asthma is incompletely understood. Although there is considerable evidence to suggest that cyclooxygenase inhibition increases LTC4 synthesis in aspirin-sensitive asthmatic subjects, there is little evidence to suggest that this occurs as a result of diversion from the cyclooxygenase pathway to the 5-lipoxygenase at the relatively low doses of aspirin required to induce the response. The finding that pretreatment of sensitised human airways in vitro with indomethacin results in increased generation of LTC4 following IgE-dependent challenge supports the view that cyclooxygenase inhibition augments increased leukotriene release. Similarly, in the guinea pig model of antigen-induced anaphylaxis, pretreatment of animals with indomethacin results in an enhancement of
Effect of ZD2138 on aspirin-induced asthma

the pulmonary mechanical response to intra-
venous antigen which is accompanied by an increased generation of LTB₄. Studies in hu-
mans with aspirin sensitivity also indicate that
increased generation of leukotrienes may con-
tribute to the mechanisms of aspirin-sensitive
asthma. Ferreri et al found that, in patients who
developed naso-ocular symptoms following in-
gestion of aspirin, concentrations of both LTC₄
and histamine from nasal lavage fluid increased
significantly from baseline values after provoca-
tion. There was no decrease in PGE₂ after
administration of the low doses of aspirin
required to induce the response. Placebo chal-
lenge with lysine-aspirin also led to
increased nasal concentrations of histamine and
LTC₄ in aspirin-sensitive subjects, but not in
aspirin-tolerant individuals. Urinary concen-
trations of LTE₄ have been used to reflect
systemic synthesis of LTC₄ following both oral
challenge with aspirin and bronchial challenge
with inhaled lysine-aspirin. Christie et al re-
ported that ingestion of aspirin which pro-
duced > 15% fall in FEV₁ was associated with a
mean fourfold increase in urinary LTE₄.
Placebo challenge for the same individuals and
aspirin challenge in asthmatic subjects tolerant
of aspirin were not associated with a change in
FEV₁, or increments in urinary LTE₄ concen-
tration. These observations were confirmed in
subsequent reports. Christie and Dah-
len et al have also reported significant rises in
urinary LTE₄ following bronchial challenge with lysine-aspirin.

In contrast to the present study ZD2138 did
not protect against allergen-induced asthma. The
designs of the allergen and aspirin chal-
lenge studies were identical and the dose of
ZD2138 used in both studies was the same.
This suggests that the mechanisms for allergen-
and aspirin-induced bronchoconstriction are
different. Aspirin-induced asthma appears to be
more dependent on 5-lipoxygenase pathway
metabolites. This is supported by our previous
finding that asthmatic patients with aspirin
sensitivity have higher basal levels of LTE₄
excretion in the urine than asthmatic patients
without aspirin sensitivity. 13,18 and the observa-
tion that subjects with aspirin-sensitive asthma
are considerably more sensitive to the broncho-
constrictor effects of inhaled LTE₄ than aspirin-tolerant asthmatic subjects. Aspirin-
induced asthma may therefore be a more perti-
nant in vivo model for assessing the poten-
tial therapeutic efficacy of this class of novel drug
than allergen challenge. Our findings emphasise
the importance of choosing the correct model
when testing the efficacy of new therapeutic
agents in man.

MK886, a FLAP inhibitor, has been shown to
inhibit allergen-induced bronchospasm. 35
Neither ZD2138 nor Zileuton inhibited
aspirin-induced bronchospasm, but both pro-
tected against aspirin-induced falls in FEV₁. 37
It remains to be evaluated whether different
classes of 5-lipoxygenase inhibitors exhibit
heterogeneity in clinical efficacy. The present
study is consistent with a significant role for
leukotrienes in the mechanisms contributing to
aspirin-sensitive asthma, since inhibition of 5-
lipoxygenase by ZD2138 led to a substantial
attenuation of the pulmonary response to as-
pirin in these patients.

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