Effect of long-term treatment with azithromycin on disease parameters in cystic fibrosis: a randomised trial

J Wolter, S Seeney, S Bell, S Bowler, P Masel, J McCormack

Background: Relentless chronic pulmonary inflammation is the major contributor to morbidity and mortality in patients with cystic fibrosis (CF). While immunomodulating therapies such as prednisolone and ibuprofen may be beneficial, their use is limited by side effects. Macrolides have immunomodulatory properties and long-term use dramatically improves prognosis in diffuse panbronchiolitis, a condition with features in common with the lung disease of CF.

Methods: To determine if azithromycin (AZM) improves clinical parameters and reduces inflammation in patients with CF, a 3-month prospective randomised double-blind, placebo-controlled study of AZM (250 mg/day) was undertaken in adults with CF. Monthly assessment included lung function, weight, and quality of life (QOL). Blood and sputum collection assessed systemic inflammation and changes in bacterial flora. Respiratory exacerbations were treated according to the policy of the CF Unit.

Results: Sixty patients were recruited (29 men) of mean (SD) age 27.9 (6.5) years and initial forced expiratory volume in 1 second (FEV1) 56.6 (22.3)% predicted. FEV1% and forced vital capacity (FVC)% predicted were maintained in the AZM group while in the placebo group there was a mean (SE) decline of –3.62 (1.78)% (p=0.047) and –5.73 (1.66)% (p=0.001), respectively. Fewer courses of intravenous antibiotics were used in patients on AZM (0.37 v 1.13, p=0.016). Median C reactive protein (CRP) levels declined in the AZM group from 10 to 5.4 mg/ml but remained constant in the placebo group (p<0.001). QOL improved over time in patients on AZM and remained unchanged in those on placebo (p=0.035).

Conclusion: AZM in adults with CF significantly improved QOL, reduced CRP levels and the number of respiratory exacerbations, and reduced the rate of decline in lung function. Long-term AZM may have a significant impact on morbidity and mortality in patients with CF. Further studies are required to define frequency of dosing and duration of benefit.

Chronic bronchial sepsis and an exuberant host inflammatory response results in bronchiectasis and, ultimately, respiratory failure in cystic fibrosis (CF). Immunomodulatory agents such as prednisolone and ibuprofen have been shown to be beneficial, but prescribing is limited because of concern regarding long-term efficacy and side effects. Macrolide antibiotics display immunomodulatory properties and are well tolerated. Long-term, low-dose erythromycin was efficacious in improving symptoms of chronic supplicative respiratory disease in patients with diffuse panbronchiolitis (DPB). Cystic fibrosis has several features in common with DPB; both conditions are characterised by chronic bacterial colonisation and a marked neutrophil infiltrate within the airways. The first suggestion that long-term macrolide therapy may also be beneficial in CF was a small study demonstrating significant improvement in lung function in seven paediatric patients who took azithromycin (AZM) daily for several months.

Randomisation: Placebo and AZM were concealed in identical capsules. Medication was randomised prior to commencement of the study by the hospital pharmacy independently of trial staff. Randomisation was in blocks of 10 (5 placebo/5 AZM) and patients were automatically dispensed the next allocated treatment (containing either AZM 250 mg or placebo daily for 3 months). Unblinding occurred after statistical analysis.

Assessment: Patients were assessed every month by lung function measured by spirometry, weight, and quality of live (QOL) survey. QOL was assessed using the Chronic Respiratory Disease Questionnaire (CRDQ) at entry and at monthly intervals. This questionnaire has been used in previous research studies and has also been investigated for its adaptation for use in CF. Scores are obtained for the domains of fatigue, mastery, emotion, dyspnoea, and total quality of life. In addition, blood was collected each month for measurement of C reactive protein (CRP), erythrocyte sedimentation rate (ESR), and sputum for microbiological analysis.
Clinical response to azithromycin in CF

To determine whether clinical improvement was due to the treatment of organisms susceptible to azithromycin, serological evidence of infection (in the absence of available molecular techniques at that time) with *Legionella pneumophila, Mycoplasma pneumoniae*, and *Chlamydia pneumoniae* at baseline and study completion was sought.

Sputum was cultured for *Pseudomonas aeruginosa*, *Burkholderia cepacia*, other typical pathogens such as *Staphylococcus aureus*, *Haemophilus influenzae*, and atypical mycobacteria. Sputum was plated onto 5% horse blood, MacConkey and senal agar with colistin, nalidixic acid, (37°C, 5% CO2), and also chocolate agar with bacitracin (anaerobic at 37°C) plus manitol salt and *Pseudocepacia* agar with ticarcillin and nalidixic acid. Colony counts were performed in duplicate on blood agar and were expressed logarithmically after incubation for 48 hours at 37°C, 5% CO2.

Table 1 Baseline characteristics of azithromycin (AZM) and placebo arms

<table>
<thead>
<tr>
<th></th>
<th>Placebo (n=30)</th>
<th>AZM (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% male</td>
<td>66.7</td>
<td>30.0</td>
</tr>
<tr>
<td>Age (years)</td>
<td>28.1 (7.3)</td>
<td>27.7 (5.6)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.71 (0.08)</td>
<td>1.66 (0.07)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.1 (12.7)</td>
<td>56.6 (9.9)</td>
</tr>
<tr>
<td>BMI</td>
<td>22.5 (3.1)</td>
<td>20.6 (2.7)</td>
</tr>
<tr>
<td>FEV1 (% pred)</td>
<td>62.3 (24.8)</td>
<td>50.9 (18.3)</td>
</tr>
<tr>
<td>FVC (% pred)</td>
<td>77.5 (19.9)</td>
<td>67.3 (19.0)</td>
</tr>
</tbody>
</table>

Values are mean (SD). BMI = body mass index; FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity.

Table 2 Mean (SD) change in FEV1 and FVC % predicted over time and by treatment group

<table>
<thead>
<tr>
<th></th>
<th>Change in FEV1 % predicted*</th>
<th>Change in FVC % predicted*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Month 1</td>
<td>Month 2</td>
</tr>
<tr>
<td>Placebo group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>-1.32 (5.51)</td>
<td>-1.17 (5.85)</td>
</tr>
<tr>
<td>AZM group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.92 (7.72)</td>
<td>1.51 (8.84)</td>
</tr>
<tr>
<td>Mean (SE) excess effect of AZM over placebo</td>
<td>3.62 (1.78)%</td>
<td>5.73 (1.66)%</td>
</tr>
</tbody>
</table>

*All changes are from baseline FEV1 % predicted and adjusted for baseline FEV1 % predicted levels in each case.*

An acute respiratory exacerbation was defined as increased cough, sputum, and/or dyspnoea, and/or reduced forced expiratory volume in 1 second (FEV1) and a decision to treat with intravenous antibiotics (either inpatient or outpatient) by the usual treating CF physician. AZM was continued throughout these periods.

Statistical analysis and sample size

The primary study outcome was change in FEV1 % predicted and was based on improvements in FEV1, reported in the open label study by Jaffe. A sample size of eight per group was required to detect a difference of 10% between drug and placebo groups with 90% power and 5% statistical significance. However, allowing for a potentially wide range of responses and anticipating loss to follow up, a sample size of 30 per group was considered optimal.

The analysis was blinded. An intention to treat analysis was performed. At the bivariate level of analysis, Fisher’s exact tests were used to test the association between independent categorical variables. McNemar’s test was used where categorical outcomes were compared over two time points (baseline and 3 months). Frequency distributions of all continuous variables were examined for outlying values and to determine whether or not they were approximately normal. The latter assumption was also formally tested with Kolmogorov-Smirnov tests for normality. Where the assumption could not be met, data were summarised in terms of medians rather than means and logarithmically transformed for analysis. Group means or log means were compared over time and by treatment group using repeated measures analysis of variance (ANOVA) models utilising a generalised estimating equations approach to accommodate the partially complete time series data (that is, all available data at each follow up point were utilised in the analyses). Trends over time were considered as categorical contrasts of each time point against baseline and, where these suggested appropriate, as linear contrasts. Models were adjusted for baseline FEV1 % predicted as a covariate since this was determined to be substantially different between the two treatment groups. Statistical significance was quoted based on the conventional p < 0.05 level (two tailed).

Analyses were performed using SUDAAN version 7.5.

RESULTS

The design of the trial is shown in fig 1.

There were no significant differences between the two groups with respect to age, number of doses missed, or number of adverse events experienced during the trial. However, the placebo group contained more men and was also on average, taller, heavier, and had better lung function than those randomised to receive AZM (table 1). The chance differences observed between the two groups were not anticipated and there were no obvious reasons for these differences.
Unless otherwise stated, these differences were accounted for in the analyses of treatment group differences over time by adjusting for sex, body mass index (BMI), and FEV1 % predicted.

There was a significant overall difference in change in FEV1 \((p=0.047)\) and FVC \((p=0.001)\) % predicted between the AZM and placebo groups. Over the 3 months of the study the mean FEV1 % predicted was 3.62% (95% confidence interval (CI) –7.13 to –0.13%) less and the mean FVC % predicted was 5.73% (95% CI –8.98% to –2.47%) less in the placebo group than in the AZM group (Table 2). The AZM group maintained lung function over time while the placebo group experienced deterioration in FEV1 and FVC % predicted. The \(p\) value for the difference between AZM and placebo and the stated difference between AZM and placebo has been adjusted for baseline FEV1 % predicted.

The AZM group had significantly fewer total days of intravenous antibiotic treatment for acute respiratory exacerbations \((p=0.009)\), fewer days at home receiving intravenous antibiotics \((p=0.037)\), and fewer courses of intravenous antibiotics during the study \((p=0.016)\). The number of days spent in hospital for antibiotic treatment of acute respiratory exacerbations was lower in the AZM group \((p=0.056)\), Table 3.

Treatment had a significant effect on the time trend of CRP measurements \((p<0.001)\). Median CRP values declined steadily over time on AZM but remained relatively constant in the placebo group (Figure 2). At baseline, CRP was significantly negatively correlated with FEV1 % predicted \((p<0.001)\) and BMI \((p=0.048)\). In patients who received AZM the reduction in CRP over time was strongly related to baseline CRP \((p<0.001)\). Patients who received AZM with a CRP level of \(>10 \mu g/ml\) at baseline had significantly poorer lung function than patients receiving AZM with a normal CRP level at baseline (mean (SD) FEV1 42 (16)% predicted \(v\) 60 (15)% predicted, \(p<0.01)\).

No statistically significant differences in ESR or BMI were detected over time, either overall or between treatment groups \((p>0.10)\) in all cases.

One patient was excluded from the end point analysis after commencing long term prednisone on the same day as the study. Fifteen patients (25%, nine placebo) did not complete the 3 months of treatment, three because of adverse events and the remainder because of non-compliance or personal request. Of the 15 patients who did not complete treatment, four stopped their medication before completing 1 month of treatment, a further five stopped before 2 months, and the remaining six stopped their medication before completing 3 months. Nineteen patients (31.7%, 12 placebo) reported missing doses of medication throughout the treatment period. Thirty one patients (16 placebo) used maintenance antibiotics (oral and/or nebulised) either continuously or intermittently during the study.

**Quality of life**

There were significant improvements in all dyspnoea scores over time overall in both groups \((p=0.042)\), Table 4. Improvements in dyspnoea, emotional, mastery and total scores were significantly higher for those receiving AZM compared with placebo. Improved fatigue scores were seen only in the AZM group.

**Adverse events**

There were 16 adverse events in 15 patients (seven on placebo). Of the three patients who discontinued treatment due to adverse events, urticarial reaction in a patient receiving AZM was considered “likely” to be related to the study drug, while neutropenia in a patient in the AZM group and “swelling” in a patient in the placebo group were considered “possibly” related to the study drug. A further two events were considered “possibly” related to the study drug (rash in each of

![Figure 2](http://www.thoraxbmi.com/)

**Figure 2.** Effect of treatment group on C reactive protein (CRP) levels over time.

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Placebo</th>
<th>AZM</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of courses of IV treatment</td>
<td>1.1 (0.5, 0–7)</td>
<td>0.4 (0, 0–2)</td>
<td>0.016</td>
</tr>
<tr>
<td>Total days IV treatment</td>
<td>7.1 (1, 0–44)</td>
<td>2.0 (0, 0–17)</td>
<td>0.009</td>
</tr>
<tr>
<td>Total days home IV treatment</td>
<td>2.1 (0, 0–14)</td>
<td>0.2 (0, 0–5)</td>
<td>0.037</td>
</tr>
<tr>
<td>Total hospital days</td>
<td>5.2 (0, 0–36)</td>
<td>2.1 (0, 0–15)</td>
<td>0.056</td>
</tr>
</tbody>
</table>

Values are mean (median, range).

---

214 Wolter, Seeney, Bell, et al
the AZM and placebo groups). All events resolved without complication.

Microbiology

Fifty seven patients had sputum analysis at baseline. A mucoid strain of *P aeruginosa* was isolated from 83.3% of subjects and a non-mucoid strain from 66.6%. *S aureus* was isolated from 41.3% of patients tested at baseline, *B cepacia* from four patients, and *H influenzae* from one patient. No mycobacteria were isolated during the course of the study. 77% of the *S aureus* isolates from the AZM group and 69.2% from the placebo group were sensitive to erythromycin.

There was no significant difference in organisms isolated or bacterial counts between the two groups at baseline, nor in the type or quantity of microorganisms at the final assessment (p>0.095 in all cases). The presence of *B cepacia, S aureus, mucoid and non-mucoid forms of P aeruginosa* was not influenced by sex, but the presence of *S aureus* was significantly correlated with reduced dyspnoea scores (p=0.021).

There was no evidence to suggest that clinical improvement was due to treatment of bacteria susceptible to macrolide therapy. Twenty nine patients underwent serological tests before and after treatment and a further 22 patients had incomplete testing (only initial titres performed). Only one patient (in the placebo group) had a fourfold rise in chlamydia and mycoplasma titres.

**DISCUSSION**

This is the first prospective randomised, double blind, placebo controlled trial of oral AZM in CF. Treatment with AZM significantly reduced the rate of decline in FEV1, and FVC % predicted over time compared with placebo. AZM treatment was associated with significantly fewer acute respiratory exacerbations requiring intravenous antibiotics and significantly improved QOL scores compared with placebo. There was evidence of reduced host systemic inflammation with a decline in CRP levels over time in subjects receiving AZM.

Randomisation was moderately successful with the exception of sex, lung function, and weight, biasing the results in favour of a reduced effect of AZM. The imbalance was considered to be of clinical significance and adjustments were made in the modelling. Stratification for disease severity within the groups was not performed. While it may be argued that those with a more severe phenotype may have had a greater scope for improvement, it is important to note that all parameters were adjusted for baseline values in the statistical analysis, reducing the chance of any observed difference being the result of reversion to the mean.

The natural history of CF is one of persistent pulmonary inflammation as a consequence of chronic bacterial infection, resulting in intermittent exacerbations of pulmonary symptoms and with temporary clinical improvement after treatment. More severe disease is generally associated with more frequent exacerbations requiring intravenous treatment. Although randomisation produced two clinically dissimilar groups, all patients were stable before enrolment. Despite evidence that the group randomised to receive AZM had more severe disease than the placebo group, they required significantly fewer courses of intravenous antibiotics and fewer days of intravenous treatment during the study period. Furthermore, patients in the AZM group had higher baseline CRP levels and treatment was associated with significant reductions in CRP despite fewer courses of systemic antibiotics. This finding provides strong evidence that the small but significant differences in lung function between the two groups and the significant reduction in systemic inflammation over time in the AZM group represent real benefit to patients receiving AZM and supports a systemic anti-inflammatory effect.

The small changes in lung function seen in this study contrast with those reported by Jaffe et al who reported an increase of 11% in FEV1 % predicted after treatment with AZM. The mean age of patients in their study was 12.1 years and the mean duration of AZM treatment was 6 months compared with a mean age of 27.9 years and maximum treatment duration of 3 months in our study. Although changes in lung function were small, the differences from placebo were statistically significant. Treatment of an older group with potentially more advanced and permanent lung disease may limit any benefit achievable with anti-inflammatory therapy. Patients in this study generally had more severe disease than in the study of Jaffe et al which is likely to be responsible for the smaller FEV1 response to treatment. We have demonstrated maintenance rather than improvements in lung function in a group with severe disease. Over the 3 months of the study the placebo group experienced a change in FEV1 % predicted of −0.91%, which equates to a drop of approximately 3–4% over 12 months. These changes are similar to changes in FEV1 reported by Ramsey et al in a study to determine the effect of inhaled tobramycin in CF. Over a 20 week treatment period they reported a fall in FEV1 % predicted of 2.64% in their adult placebo group which equates to a change of approximately 6–7% over a 12 month period. Maximum benefits of such treatment may be achieved in subjects without established disease. Trials in children or with populations large enough to allow stratification of results based on disease severity are necessary to assess maximum achievable benefits from early onset of treatment.

At the time of this trial there was no validated disease-specific questionnaire available for the measurement of QOL in CF. The QOL questionnaire used for this study was the CRDQ, developed for use in patients with chronic obstructive pulmonary disease (COPD) who share many clinical features in common with CF patients on a day to day basis. This questionnaire has been used in a previous clinical trial with adult CF patients and has also been validated for its adaptation for use in CF.

| Table 4 Mean (SD) QOL scores over time: baseline and final assessment (month 3) |
|----------------------|----------------------|----------------------|----------------------|
|                      | Placebo             | Azithromycin         |                      |
|                      | n | QOL score | p value* | n | QOL score | p value* |
| Dyspnoea (range 5–35)** Final | 28 | 22.75 (4.86) | 0.042 | 28 | 21.96 (4.68) | 0.042 |
| Emotion Baseline | 19 | 25.82 (5.27) | 0.001 | 22 | 24.16 (4.76) | 0.001 |
| Emotion Final | 30 | 18.87 (5.37) | 0.012 | 30 | 17.17 (5.50) | 0.012 |
| Emotion (range 4–28) Final | 20 | 18.85 (4.70) | 0.012 | 24 | 18.04 (4.12) | 0.012 |
| Fatigue Baseline | 30 | 37.97 (6.84) | 0.012 | 30 | 34.87 (7.63) | 0.012 |
| Fatigue Final | 20 | 39.70 (5.66) | 0.012 | 24 | 41.33 (7.13) | 0.012 |
| Fatigue (range 7–49) Final | 20 | 24.37 (3.69) | 0.035 | 20 | 22.70 (5.47) | 0.035 |
| Master Baseline | 30 | 25.25 (3.64) | 0.035 | 30 | 24.54 (3.45) | 0.035 |
| Master Final | 20 | 103.14 (14.00) | 0.035 | 29 | 95.72 (18.68) | 0.035 |
| Master (range 20–140) Final | 20 | 109.30 (14.78) | 0.035 | 23 | 116.11 (14.67) | 0.035 |

*Interaction of treatment effect and time. **Minimum and maximum score possible for each domain.*
There was no evidence that AZM influenced the microbiological profile of sputum after 3 months of treatment. Improvement was not related to a bacterial effect on organisms sensitive to AZM. However, in the absence of accessible molecular techniques, serological testing was performed to determine whether clinical improvement was due to the treatment of susceptible organisms. Serological testing may have been inadequate to rule out an acute infection.

AZM was chosen over other macrolides such as erythromycin because of a superior gastrointestinal side effect profile and ease of administration. It was well tolerated but, despite a once daily regimen, adherence with treatment was moderate with almost one third of patients reporting missed doses at some time during the trial. These adherence levels were within the range of previously published studies of adherence in chronic diseases, including CF, which quote ranges of non-adherence from 15% to 50% for most areas of treatment.

Although relatively costly, long term treatment with AZM may result in direct cost reductions associated with reduced number of acute respiratory exacerbations requiring intravenous antibiotic therapy as well as reduced indirect costs associated with improved QOL. Although the outcomes of this study are promising, the choice of macrolide, dose, dose interval, duration of effect, and impact of long term treatment on disease progression and the microbiological environment of the lung are unknown. Macrolides including AZM accumulate intracellularly, but concentration/ effect ratios are poorly defined both for the treatment of infection and inflammation. Reports of reduced adherence of bacteria to epithelial cells after twice weekly AZM suggest that less frequent dosing than was used in this trial may be possible.

The mechanism by which macrolides downregulate the host inflammatory response is unclear but is almost certainly multifactorial. Suppression of interleukin (IL)-8 secretion may be important via inhibition of IL-8 gene transcription. Other effects include suppression of tumour necrosis factor (TNF)-α synthesis and modulation of IL-1 and GM-CSF production by lipopolysaccharide stimulated monocytes. Macrolides also interfere with neutrophil function. In addition to effects on the host immune response, macrolides inhibit alginate production, protease activity, flagellin expression, and bacterial motility of P. aeruginosa. AZM reduces adherence of P. aeruginosa to epithelial cells, opening the possibility of a preventative role for these agents.

In summary, we have shown that long term oral AZM treatment is associated with improvements in several key disease indicators in CF. Treatment with AZM was associated with a significantly reduced rate of decline in lung function over a 3 month period. It significantly improved CRP levels as a marker of systemic inflammation, QOL, and reduced the number of acute respiratory exacerbations compared with placebo. We conclude that macrolides may have a role in the long term management of patients with CF.

ACKNOWLEDGEMENTS

This project was supported by The John P Kelly Mater Research Foundation and The Mater Hospital Private Practice Fund. Azithromycin and placebo capsules were donated by Pfizer.

Authors’ affiliations

J Walter, S Seeney, J McCormack, University Department of Medicine and Department of Infectious Disease, Mater Adult Hospital, Brisbane, Australia

S Bell, P Masel, The Adult Cystic Fibrosis Unit, The Prince Charles Hospital, Brisbane, Australia

S Bowler, Department of Respiratory Medicine, Mater Adult Hospital, Brisbane, Australia

REFERENCES


www.thoraxjnl.com
Effect of long term treatment with azithromycin on disease parameters in cystic fibrosis: a randomised trial

J Wolter, S Seeney, S Bell, S Bowler, P Masel and J McCormack

Thorax 2002 57: 212-216
doi: 10.1136/thorax.57.3.212

Updated information and services can be found at:
http://thorax.bmj.com/content/57/3/212

These include:

References
This article cites 23 articles, 9 of which you can access for free at:
http://thorax.bmj.com/content/57/3/212#BIBL

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections
Articles on similar topics can be found in the following collections

- Inflammation (1020)
- Epidemiologic studies (1829)
- Airway biology (1100)
- Lung function (773)
- Cystic fibrosis (525)
- Drugs: infectious diseases (968)
- Pneumonia (infectious disease) (579)
- Pneumonia (respiratory medicine) (562)
- TB and other respiratory infections (1273)
- Bronchiolitis (112)
- Bronchitis (235)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/