Oral almitrine in treatment of acute respiratory failure and cor pulmonale in patients with an exacerbation of chronic obstructive airways disease

PA Bardsley, JT Tweney, NM Morgan, PH Howard

Abstract
The effects of oral almitrine bismesylate, a respiratory stimulant that acts on peripheral arterial chemoreceptors, was studied in patients with chronic obstructive airways disease and hypoxaemic cor pulmonale. Twenty-three patients admitted to hospital with an acute exacerbation of ventilatory failure were randomised to receive either almitrine 100 mg twice a day reducing to 50 mg twice a day over 48 hours or placebo in addition to conventional treatment. On admission the mean (SE) values for blood gas tensions were Pao2 4.8 (0.3) and Paco2 7.7 (0.3) kPa in the 12 patients who received almitrine and Pao2 4.9 (0.1) and Paco2 7.6 (0.3) kPa in the 11 who received placebo. After three hours of oxygen therapy at 1 l/min there was a similar rise in Pao2 in both groups, 6.4 (0.2) kPa in those receiving almitrine and 6.6 (0.4) kPa in those receiving placebo. After 24 hours of oxygen therapy values of Pao2, were again similar at 6.3 (0.8) kPa and 6.7 (2.2) kPa respectively. Arterial blood gas tensions improved during the study in those who survived but no significant differences were apparent between the two groups. There were six deaths, five in the almitrine group and one in the placebo group. There were no differences between the groups in respiratory rate, results of spirometry, oxygen requirement, or degree of dyspnoea (on visual analogue scale). The results did not show any benefit from oral almitrine in patients with acute respiratory failure secondary to chronic obstructive airways disease. Plasma almitrine concentrations, however, were often below the optimum therapeutic range, suggesting impaired drug absorption.

Almitrine bismesylate is a recently developed respiratory stimulant that acts on peripheral chemoreceptors, principally of the carotid body, to increase tidal volume. It also causes pulmonary vasoconstriction and may have beneficial effects on ventilation or perfusion matching within the lung. Oral almitrine 100–200 mg daily when taken for up to a year improves arterial blood gas tensions in patients with stable hypoxaemic chronic obstructive airways disease. Little information is available on the effect of the drug in patients with an acute exacerbation of chronic bronchitis and emphysema associated with acute ventilatory failure.

In theory almitrine, like other respiratory stimulants, would be an attractive means of reducing the requirement for oxygen and of limiting excessive hypercapnia during low flow oxygen therapy. It has the advantage that it can be taken orally. There is some evidence that intravenous almitrine can improve arterial oxygen tensions in patients with chronic obstructive airways disease and acute ventilatory failure, but concern was expressed in one study because pulmonary artery pressure rose in all 12 patients, four of whom complained of malaise and increased dyspnoea. There are few studies of oral almitrine in patients with this condition and none has looked specifically at patients with hypoxaemic cor pulmonale. Patients with acute on chronic ventilatory failure given oral almitrine in a double blind study over two weeks did not show any improvement in blood gas tensions until day 10, and in another study oral almitrine did not reduce the requirement for assisted ventilation.

Whether almitrine has a useful role in the treatment of acute ventilatory failure secondary to chronic obstructive airways disease has not been established clearly, and whether the drug is associated with a more rapid recovery or, more importantly, a reduction in the appreciable mortality associated with this condition is not known. We examined the effect of oral almitrine on arterial blood gas tensions, inspired oxygen requirement, symptoms, and survival in patients with acute respiratory failure and hypoxaemic cor pulmonale secondary to an exacerbation of chronic obstructive airways disease.

Methods

PATIENTS
We studied 23 patients with chronic obstructive airways disease and hypoxaemic cor pulmonale admitted to hospital with an acute exacerbation of ventilatory failure. Patients were randomly allocated to receive oral almitrine or placebo in a double blind manner in addition to conventional treatment. The criteria for entry into the study were respiratory failure with arterial oxygen tension (Pao2) less than 8.0 kPa on admission to hospital and arterial carbon dioxide tension (Paco2)
greater than 6.0 kPa while breathing room air; peripheral oedema on clinical examination; a forced expiratory volume in one second (FEV$_1$) less than 1.5 (recorded either in the past or when clinically stable); and a forced expiratory ratio (FEV$_1$/forced vital capacity (FVC)) of less than 70%. Patients with asthma, reversible airflow obstruction, interstitial pulmonary fibrosis, chest wall disorders, or neuromuscular disorders were excluded, as were those with clinically relevant cardiac, renal, or hepatic disease. No patients had received almitrine or any other respiratory analectic within the previous two months.

**ASSESSMENT AND STANDARD TREATMENT**

On admission a clinical assessment was made and an arterial blood sample taken. If the patient had received oxygen the arterial sample was taken after this had been stopped for at least 30 minutes. If the entry criteria were fulfilled informed consent was obtained and the patient entered into the study. A venous blood sample was taken for standard haematological and biochemical testing, chest radiography and electrocardiography were performed, and sputum was sent for microbiological analysis. All patients were then scored on a visual analogue scale (0–100 mm) for sense of wellbeing and degree of breathlessness (for wellbeing 0 = feeling ill, 100 = feeling well; for breathlessness 0 = not breathless, 100 = extremely short of breath).

Oxygen was given initially at a flow rate of 1 l/min through nasal cannulas, and oral almitrine 100 mg or placebo was then given. All patients were treated in the standard way with chest physiotherapy, an antibiotic (usually amoxycillin 500 mg three times a day or trimethoprim or erythromycin if the patient was allergic to penicillin), intravenous salbutamol (10 mg in 50 ml of physiological saline infused over 24 hours), and diuretics (oral frusenem 80 mg and spironalactone 100 mg daily). After three hours a venous blood sample was taken to determine the plasma almitrine concentration and a further arterial sample taken. If the PaO$_2$ had decreased or remained constant the inspired oxygen flow rate was increased to 1.5 l/min, if it had increased by less than 1 kPa the oxygen flow rate was left at 1.0 l/min, and if it had increased by more than 1 kPa the flow rate was reduced to 0.5 l/min. Blood was taken for estimation of the plasma almitrine concentration at five, eight, and 12 hours. Arterial blood gas tensions were rechecked again after 24 hours of treatment and as indicated clinically.

**DRUG TREATMENT**

Almitrine was given 100 mg twice daily with food for 24 hours followed by 100 mg in the morning and 50 mg in the evening for a further 24 hours and 50 mg twice daily with food for the next 18 days. Patients received chest physiotherapy twice daily and were not allowed to smoke. Fluid intake was initially restricted to 1 litre per day; the diuretics continued for the duration of the trial. When the PaO$_2$ had risen above 8 kPa for 24 hours the intravenous infusion of salbutamol was stopped and this drug was given by nebuliser (5 mg/5 ml four times a day). Antibiotic treatment was continued for 10 days. Other drug treatment on admission, including any corticosteroids, was continued unchanged.

**MONITORING OF PATIENTS**

The study was continued for three weeks. Patients were assessed each morning and arterial blood gas tensions checked before almitrine was given. Inspired oxygen concentration was adjusted to try to maintain PaO$_2$ at around 8 kPa. Respiratory rate, results of spirometry, and visual analogue scores were recorded daily during the first week and then on alternate days. On these days the oxygen flow rate was also checked with a rotameter. On days 2, 4, 7, 14, and 21 venous blood samples were taken for estimation of the blood count and electrolyte and plasma almitrine concentrations. Blood samples were taken two to three hours after administration of almitrine, when peak plasma concentrations would be expected. At the end of the study arterial blood gas tensions were recorded with the patient breathing air after having stopped receiving oxygen for at least four hours.

All arterial blood samples were analysed immediately with a Corning 170 machine and spirometry was performed with a portable spirometer (Micro Medical Instruments). Plasma almitrine concentrations were measured by gas–liquid chromatography to a sensitivity of 5 ng/ml. The study was approved by the hospital ethics committee.

**STATISTICAL ANALYSIS**

Patients withdrawn from the study were included in the analysis. Mean values and standard errors (SE) of measurements are given. Measurements on entry into and during the study were compared between and within groups with a paired or unpaired Student’s t test as appropriate. Survival be-

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**Table 1 Characteristics of patients randomly allocated to receive almitrine or placebo (mean (SE) values)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients receiving almitrine ($n = 12$)</th>
<th>Patients receiving placebo ($n = 11$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>65.0 (0.20)</td>
<td>72.0 (0.20)*</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>6/6</td>
<td>8/3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.0 (6.0)</td>
<td>59.0 (5.0)</td>
</tr>
<tr>
<td>PaO$_2$ (kPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>4.8 (0.3)</td>
<td>4.9 (0.3)</td>
</tr>
<tr>
<td>After three hours</td>
<td>6.0 (0.2)</td>
<td>6.6 (0.4)</td>
</tr>
<tr>
<td>Paco$_2$ (kPa):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>7.7 (0.3)</td>
<td>7.6 (0.3)</td>
</tr>
<tr>
<td>After three hours</td>
<td>8.1 (0.3)</td>
<td>8.8 (0.5)</td>
</tr>
<tr>
<td>H$^+$ concentration (nmol/l):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>44.0 (1.0)</td>
<td>43.0 (1.0)</td>
</tr>
<tr>
<td>After three hours</td>
<td>45.0 (1.0)</td>
<td>46.0 (2.0)</td>
</tr>
<tr>
<td>FEV$_1$ (l)</td>
<td>0.43 (0.1)</td>
<td>0.40 (0.1)</td>
</tr>
<tr>
<td>FVC (l)</td>
<td>1.08 (0.23)</td>
<td>0.97 (0.29)</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>27.0 (3.0)</td>
<td>28.0 (3.0)</td>
</tr>
<tr>
<td>Visual analogue score for dyspnoea (mm)</td>
<td>56.0 (11.0)</td>
<td>43.0 (8.0)</td>
</tr>
<tr>
<td>Visual analogue score for wellbeing (mm)</td>
<td>33.0 (9.0)</td>
<td>44.0 (7.0)</td>
</tr>
<tr>
<td>Packed cell volume</td>
<td>49.0 (2.0)</td>
<td>43.0 (2.0)</td>
</tr>
</tbody>
</table>

*p < 0.05.

PaO$_2$—arterial oxygen tension; Paco$_2$—arterial carbon dioxide tension; FEV$_1$—forced expiratory volume in one second; FVC—forced vital capacity.
Table 2  Details of six patients who died during study

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Sex (M/F)</th>
<th>Receiving almitrine or placebo</th>
<th>Blood gas tensions on admission (kPa)</th>
<th>Blood gas tensions within 24 hours after death (kPa)</th>
<th>Oxygen flow rate (l/min)</th>
<th>Day of death</th>
<th>Further details</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>M</td>
<td>Almitrine</td>
<td>PAO₂ 4 3, PA CO₂ 7 3</td>
<td>PAO₂ 4 6, PA CO₂ 8 3</td>
<td>1 0</td>
<td>5</td>
<td>Haemophilus influenzae infection</td>
</tr>
<tr>
<td>74</td>
<td>F</td>
<td>Almitrine</td>
<td>PAO₂ 4 9, PA CO₂ 8 8</td>
<td>PAO₂ 5 2, PA CO₂ 9 2</td>
<td>1 5</td>
<td>2</td>
<td>Severe emphysema at postmortem examination</td>
</tr>
<tr>
<td>68</td>
<td>M</td>
<td>Almitrine</td>
<td>PAO₂ 5 9, PA CO₂ 7 2</td>
<td>PAO₂ 5 5, PA CO₂ 8 0</td>
<td>2 0</td>
<td>3</td>
<td>Died in respiratory failure</td>
</tr>
<tr>
<td>68</td>
<td>F</td>
<td>Almitrine</td>
<td>PAO₂ 3 6, PA CO₂ 8 1</td>
<td>PAO₂ 7 2, PA CO₂ 10 4</td>
<td>1 0</td>
<td>7</td>
<td>No postmortem examination</td>
</tr>
<tr>
<td>71</td>
<td>M</td>
<td>Almitrine</td>
<td>PAO₂ 4 0, PA CO₂ 6 2</td>
<td>PAO₂ 7 1, PA CO₂ 8 2</td>
<td>1 0</td>
<td>3</td>
<td>Died in ambulance during transfer to intensive therapy unit</td>
</tr>
<tr>
<td>77</td>
<td>M</td>
<td>Placebo</td>
<td>PAO₂ 5 8, PA CO₂ 6 8</td>
<td>PAO₂ 4 2, PA CO₂ 10 2</td>
<td>0 5</td>
<td>2</td>
<td>Sudden cardiorespiratory arrest</td>
</tr>
</tbody>
</table>

Results

We studied 23 patients (14 men and nine women; age 51–82 years) with severe airflow obstruction (FEV₁ 0:21–1:11 l) and ventilatory failure (on admission to hospital arterial blood gas tensions breathing air were PAO₂ 3 2–6 7 kPa and PA CO₂ 6 2–10 0 kPa). Twelve patients were treated with almitrine and 11 with placebo. Table 1 shows the patients’ characteristics on entry to the study.

Treatment was well tolerated and no patient complained of any symptom that could be attributed to the drug. Seventeen patients completed the study. No patient was withdrawn owing to side effects of the drug. Six patients died, five of those receiving almitrine and one receiving placebo. Details of the deaths are given in table 2. The difference in death rate between the two groups was not significant (p = 0 09).

There were no significant differences in arterial blood gas tensions or oxygen flow rates. After three hours of oxygen at 1 l/min the mean PAO₂ had risen from 4 8 (0 3) to 6 4 (0 2) kPa in those receiving almitrine and from 4 9 (0 1) to 6 6 (0 4) kPa in those receiving placebo. After 24 hours of oxygen therapy mean values were 6 3 (0 8) kPa and 6 7 (2 2) kPa respectively. Figure 1 shows the mean changes in both PAO₂ and PA CO₂ from baseline over time.

Arterial blood gas tensions improved during the study and after three weeks mean arterial blood gas tensions when patients were breathing air were PAO₂ 7 1 (0 83) kPa, PA CO₂ 6 0 (0 5) kPa (n = 7) in those receiving almitrine and PAO₂ 8 1 (0 5) kPa, PA CO₂ 6 5 (0 5) kPa (n = 10) in those receiving placebo. Figure 2 gives the mean FEV₁, FVC, and respiratory rate and figure 3 gives the mean visual analogue scores for breathlessness and wellbeing. There were no significant differences between the two groups for any of these measurements. Table 3 gives the mean plasma almitrine concentrations in those receiving the drug.

Figure 1  Mean changes in PAO₂ and PA CO₂ at 3 hours and on days 2, 7, 14, and 21 for patients treated with almitrine or placebo. The numbers of patients are in parentheses. All values were obtained with the patient breathing oxygen; the mean inspired oxygen flow rates are given (bottom). Bars indicate standard errors.
therapeutic approach and has the advantages of being active when taken orally and having no central side effects. However, the use of respiratory stimulants in patients with acute ventilatory failure is controversial. They are often prescribed on the assumption that central respiratory drive is insufficient, yet it is often increased in patients with acute ventilatory failure. Concern has also been expressed about respiratory analeptics worsening dyspnoea and exacerbating respiratory muscle fatigue. Nasal intermittent positive pressure ventilation may be helpful for these patients in the future.

We assessed the effect of oral almitrine in patients with acute on chronic ventilatory failure and cor pulmonale secondary to chronic bronchitis and emphysema. All patients had severe, irreversible airflow obstruction. Patients treated with almitrine were well matched with those given placebo and all patients were treated in a standard manner with controlled oxygen, bronchodilators, chest physiotherapy, diuretics, and antibiotics.

Our regimen for giving controlled oxygen therapy was designed to try to standardise patient management as far as possible. The inspired oxygen was titrated to try to achieve a PaO₂ above 8 kPa. However, a lower PaO₂ was accepted if hypercapnia or respiratory acidosis worsened. In the first 24 hours seven patients treated with almitrine (three of whom subsequently died) and four treated with placebo had a PaO₂ while breathing oxygen of less than 6.7 kPa, mainly because of worsening hypercapnia. A PaO₂ greater than 8 kPa was often not achieved until days five to seven. Monitoring the degree of acidosis rather than the absolute PaCO₂ might have been a better guide to oxygen requirement. Six patients, three in each group, became acidic during oxygen therapy with a hydrogen ion concentration greater than 55 nmol/l (two of these patients died). There was no evidence that almitrine allowed a higher inspired oxygen concentration to be tolerated. No differences in oxygen flow rates between the groups were apparent at any stage. FEV₁ and FVC were virtually the same in the two groups and improved in both over time. The PaO₂ rose and PaCO₂ fell progressively apart from during the initial worsening of hypercapnia. The respiratory rate was higher in the patients treated with almitrine. Breathlessness was more difficult to assess, but those given almitrine had a higher symptomatic score throughout the study. There was no correlation between the degree of dyspnoea and plasma almitrine concentration. Overall, wellbeing did not differ between the two groups.

Acute ventilatory failure in patients with chronic bronchitis and emphysema is associated with a high mortality. Six of the 23 patients (26%) entered into the study died: five of those given almitrine and one of those given

### Table 3 Mean (SE) plasma almitrine concentrations for the 12 patients treated with the drug at entry (T₀) and at intervals thereafter

<table>
<thead>
<tr>
<th>T₀</th>
<th>3 h</th>
<th>5 h</th>
<th>8 h</th>
<th>12 h</th>
<th>Day 2</th>
<th>Day 4</th>
<th>Day 7</th>
<th>Day 14</th>
<th>Day 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SE) almitrine concentration (µg/l)</td>
<td>0 (0)</td>
<td>150 (35)</td>
<td>113 (22)</td>
<td>153 (82)</td>
<td>209 (88)</td>
<td>90 (38)</td>
<td>127 (44)</td>
<td>95 (30)</td>
<td>156 (38)</td>
</tr>
</tbody>
</table>

**Discussion**

Patients with acute ventilatory failure secondary to an exacerbation of chronic obstructive airways disease are treated initially with controlled oxygen. If an acceptable PaO₂ cannot be achieved without incurring excessive hypercapnia with worsening respiratory acidosis assisted ventilation must be considered. The difficulties of weaning such patients from assisted ventilation are widely recognised and so many patients are treated with the respiratory stimulant doxapram by intravenous infusion while other treatment starts to take effect. The non-specific arousal produced by doxapram often limits its use. Almitrine offers a different

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Oral almitrine for acute respiratory failure and cor pulmonale in patients with an exacerbation of chronic obstructive airways disease

Figure 3 Visual analogue (VA) scores for breathlessness and wellbeing on a 0–100 mm scale (0 = not breathless and 100 = extremely short of breath) and for wellbeing (0 = feeling ill and 100 = feeling well). Values are means with standard errors.

Figure 3

oral almitrine is about 70% of that of an intravenous dose, and the pharmacokinetics in patients with chronic obstructive airways disease do not differ appreciably from those in healthy subjects.6 Higher oral doses could be tried, but in stable patients doses above 100 mg a day tend to be associated with a high incidence of side effects such as nausea, abdominal discomfort, headache, and flushing.17 We did not find any significant correlation between arterial blood gas tensions and plasma almitrine concentrations.

Our results do not show any beneficial effects of oral almitrine in the treatment of acute ventilatory failure and cor pulmonale secondary to chronic obstructive airways disease. For the present this drug is better suited to the treatment of chronic than of acute respiratory failure.

We thank Servier Laboratories (United Kingdom) for measuring blood almitrine concentrations.


Proposed oral almitrine dosage. The slow rise in blood concentrations suggests impaired absorption, probably due to severe hypoaemia and oedema of the bowel wall affecting gastrointestinal function. The bioavailability of oral almitrine is about 70% of that of an intravenous dose, and the pharmacokinetics in patients with chronic obstructive airways disease do not differ appreciably from those in healthy subjects. Higher oral doses could be tried, but in stable patients doses above 100 mg a day tend to be associated with a high incidence of side effects such as nausea, abdominal discomfort, headache, and flushing. We did not find any significant correlation between arterial blood gas tensions and plasma almitrine concentrations.

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