Albendazole is a benzimidazole derivative used for treatment of intestinal helminthiasis and echinococcosis. Albendazole is an effective drug for treatment of these diseases but the therapeutic response in echinococcosis is poorly predictable due to the poor bioavailability. Albendazole, a mixture of R(+)- and S(−)-enantiomers. Formation of R(+)-ABSZX is catalyzed by microsomal flavin monooxidase (FMO) and of S(−)-ABSZX by cytochrome P450 enzymes (CYP3A). The extent to which both enzyme systems contribute to this process is variable from species to species and not well known in humans. This so-called first-pass effect of albendazole is almost 100%. Subsequently, ABZSX is converted by other cytochrome P450 enzymes (CYP2C) into the inactive metabolite albendazole sulfone. In plasma, ABZSX is readily detectable by high-pressure liquid chromatography (HPLC). The parent compound and the inactive metabolite are present in very low concentrations. It is not well known which ABZSX concentrations are reached at the usual and supertherapeutic albendazole doses and which concentrations are required for an appropriate therapeutic response. In vitro and in vivo studies demonstrated, however, that ABZSX concentrations in cyst fluid of 0.50 mg/L and higher were scolecidal and that long-term treatment improved outcome.

Several pharmacokinetic studies have shown that combining albendazole with a fatty meal results in a 4- to 8-fold increase of ABZSX Cmax and of the areas under the curve (AUC) of ABZSX concentration versus time. In contrast, in one study no increase in Cmax was demonstrated when albendazole was combined with a fatty meal. The inter-individual variability in these studies was great. Therefore, it is unclear whether increasing the albendazole dose results in a linear increase of albendazole bioavailability, although a proportional increase of ABZSX concentration was reported after administration of a 50% greater dose of albendazole.

Attention has recently been drawn to the beneficial effect of cimetidine co-administration with albendazole. Patients with echinococcosis treated with the combination of albendazole and cimetidine had fewer viable cysts and higher ABZSX concentrations in cyst fluid and bile than patients treated with albendazole alone. Serum ABZSX concentrations were not different. The pharmacologic basis of this observation has not been elucidated but it is possible that inhibition of gastric acid secretion and mucosal and hepatic CYP enzymes by cimetidine plays a role. The overall effect of cimetidine co-administration on plasma ABZSX concentrations is not well defined. In the present report, we studied plasma ABZSX concentrations in relation to albendazole dose and the effect of cimetidine co-administration on ABZSX concentration.

INTRODUCTION

Albendazole is a benzimidazole derivative used for treatment of intestinal helminthiasis and echinococcosis. Albendazole is an effective drug for treatment of echinococcosis and is not well known in humans. This so-called first-pass effect of albendazole is almost 100%. Subsequently, ABZSX is converted by other cytochrome P450 enzymes (CYP2C) into the inactive metabolite albendazole sulfone. In plasma, ABZSX is readily detectable by high-pressure liquid chromatography (HPLC). The parent compound and the inactive metabolite are present in very low concentrations. It is not well known which ABZSX concentrations are reached at the usual and supertherapeutic albendazole doses and which concentrations are required for an appropriate therapeutic response. In vitro and in vivo studies demonstrated, however, that ABZSX concentrations in cyst fluid of 0.50 mg/L and higher were scolecidal and that long-term treatment improved outcome.

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MATERIALS AND METHODS

Study subjects. Six healthy male volunteers (age 19–21 years; weight 55–92 kg; body mass index 17–25 kg/m²) participated. Albendazole was administered with water on an empty stomach after an overnight fast. Food was withheld for 4 hours after the drug was taken but non-coffeeine and non-alcoholic beverages were allowed. Subsequently, a light meal was offered and other dietary restrictions were removed. The light meal consisted of a cheese roll, 150 ml skimmed milk, and an apple (30 g fat, 49 g carbohydrates, 25 g protein, 575 kcal).

Albendazole (SmithKline Beecham) from one batch was provided by the hospital pharmacy as a powder in capsules and administered as a single oral dose: 5, 10, 20, or 30 mg/kg body weight. The actual albendazole doses were within 3% of calculated doses and were administered in a randomized order with at least a one-week wash-out period. In a separate study, albendazole (20 mg/kg) was combined with cimetidine (SmithKline Beecham, 10 mg/kg twice daily). Cimetidine was started 48 hours before the study and continued during the study.

Immediately before and 1, 2, 3, 4, 6, 8, 11, 24, and 36 hours after drug administration venous blood samples were taken from an indwelling catheter placed in the lower arm. Blood was collected into heparinized tubes, centrifuged im-
mediated and plasma samples were stored at minus 70 °C until assayed.

Written informed consent was obtained from all volunteers. The study was approved by the Institutional Review Board of the Academic Medical Center, Amsterdam.

**Albendazole sulfoxide assay.** ABZSX concentrations were measured according to a modified method.

The subjects did not encounter adverse events from the single, high doses of albendazole. ABZSX concentrations could be readily detected in the HPLC assay. The concentrations of the parent compound albendazole and the inactive metabolite albendazole sulphoxon were too low for quantitation. After administration of albendazole, a remarkable variability was observed among individual subjects at every dose given (Figure 1). The coefficient of variation for C\text{max} varied from 38–72% and for AUC\text{0–24} from 29–71%, independent of the albendazole dose (Table 1).

Intra-individual variability of ABZSX concentrations was also great and is illustrated in Figure 2 for subject A. The highest ABZSX concentrations were detected with a dose of 20 mg/kg albendazole. Administration of 30 mg/kg resulted in lower levels than 5 mg/kg and only slightly higher concentrations than 10 mg/kg. When data from all six subjects at the four different albendazole doses were compared as a group, the mean ABZSX concentration versus time curves overlapped with the lower albendazole doses (5 and 10 mg/kg), and there was a stepwise increase after administration of 20 and 30 mg/kg albendazole (Figure 3). The increase in mean C\text{max} and AUC\text{0–24} was neither linear nor significant due to the great intra- and inter-individual variability of albendazole concentrations (P values 0.217 and 0.221, respectively). The elimination half-lives following all four doses was 7.9 ± 3.6 hours and was not dose dependent (P = 0.261). T\text{max} was reached 2.7 ± 0.8 hr after drug administration.

![FIGURE 1. C\text{max} of ABZSX in six healthy male subjects after administration of single oral doses of 5, 10, 20, or 30 mg/kg albendazole. Each subject is indicated by a different symbol.](image)

**TABLE 1**

<table>
<thead>
<tr>
<th>Albendazole (mg/kg)</th>
<th>C\text{max} (mg/L)</th>
<th>AUC\text{0–24} (mg·h/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.21 ± 0.14</td>
<td>1.92 ± 1.37</td>
</tr>
<tr>
<td>10</td>
<td>0.24 ± 0.09</td>
<td>2.08 ± 0.61</td>
</tr>
<tr>
<td>20</td>
<td>0.29 ± 0.21</td>
<td>2.72 ± 1.86</td>
</tr>
<tr>
<td>30</td>
<td>0.39 ± 0.19</td>
<td>3.68 ± 1.52</td>
</tr>
<tr>
<td>20 + cimetidine</td>
<td>0.14 ± 0.03</td>
<td>1.95 ± 0.35</td>
</tr>
</tbody>
</table>

**RESULTS**

The subjects did not encounter adverse events from the single, high doses of albendazole. ABZSX concentrations could be readily detected in the HPLC assay. The concentrations of the parent compound albendazole and the inactive metabolite albendazole sulphoxon were too low for quantitation. After administration of albendazole, a remarkable variability was observed among individual subjects at every dose given (Figure 1). The coefficient of variation for C\text{max} varied from 38–72% and for AUC\text{0–24} from 29–71%, independent of the albendazole dose (Table 1).

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![FIGURE 2. ABZSX concentration versus time curves in subject A after administration of single oral doses of 5, 10, 20, or 30 mg/kg albendazole.](image)
Albendazole is an antihelminthic drug that mainly acts on intestinal parasites. It is poorly absorbed and reaches high intraluminal but low systemic concentrations. Despite its poor absorption, albendazole is also used for the treatment of systemic parasitic infections like echinococcosis because alternative drugs are not available. In most pharmacokinetic studies designed to investigate how to increase the concentrations of the active metabolite ABZSX, intra-individual and inter-individual variability was high. Our data show a similar pattern. Intra-individual variability cannot be estimated accurately in the current study but is illustrated by the course of \( C_{\text{max}} \) in the six subjects (Figure 2). The inter-individual variability of mean \( C_{\text{max}} \) at four different doses varied from 38%–72% and was not dose-dependent. Due to this variability, increasing the albendazole dose 6-fold did not result in a linear or significant increase in mean \( C_{\text{max}} \). After administration of 5, 10 or 20 mg/kg albendazole mean \( C_{\text{max}} \) was almost identical. Only after 30 mg/kg albendazole did mean \( C_{\text{max}} \) increase but the difference between the lowest and the highest dose was not significant. For treatment of echinococcosis, the recommended dose of albendazole is usually 5 mg/kg whereas to our knowledge a dose of 30 mg/kg is never used.

![Graph showing mean ABZSX concentration versus time curves in six healthy male subjects after administration of single oral doses of 5, 10, 20, or 30 mg/kg albendazole.](image)

**Discussion**

Remarkably, inter-individual variability of \( C_{\text{max}} \) and \( \text{AUC}_{0-24} \) was significantly lower when cimetidine was co-administered. The coefficients of variation for \( C_{\text{max}} \) were 14% versus 72% and for \( \text{AUC}_{0-24} \) 18% versus 68%. Cimetidine reduced mean \( C_{\text{max}} \) by 52% without reaching significance (\( P = 0.109 \)). Mean \( \text{AUC}_{0-24} \) did not change significantly during cimetidine co-administration (\( P = 0.400 \)) because the 2.6-fold prolongation of the elimination half-life (\( P = 0.028 \)) compensated for the lower ABZSX concentrations. No increase of the parent compound albendazole was observed during cimetidine co-administration.

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The mechanism underlying the high inter-individual variability of ABZSX concentrations is not known. It may be hypothesized that gastric acidity plays a role. In the present study, albendazole was administered with water, without food, and after an overnight fast. In such a situation, gastric acid secretion is likely to vary among individuals. When this variability is minimized by inhibiting gastric acid secretion with cimetidine, two effects on ABZSX concentrations may be observed if absorption is pH dependent. It may decrease such as is the case with itraconazole and there may be less inter-individual variability. We observed both impaired and less variable absorption. Cimetidine co-administration tended to decrease mean \( C_{\text{max}} \) by 52%, and inter-individual variability was low compared to albendazole alone (14% versus 72%). This observation suggests that the absorption of albendazole is indeed pH dependent, with better absorption at lower pH. Cimetidine may however exert additional actions that affect albendazole pharmacokinetics. Cimetidine inhibits the activity of hepatic CYP enzymes. It may be speculated that the CYP-mediated metabolic conversion of albendazole into the S(−)-enantiomer is inhibited and thus making the FMO-mediated pathway a rate limiting factor for R(+) enantiomer formation. This may result in lower ABZSX concentrations. However, this mechanism of action is tentative and needs further study. A better defined effect of cimetidine is the increase of concentrations of drugs that are metabolized by these CYP enzymes, such as mebendazole. Therefore, the metabolism of ABZSX, which is also CYP dependent, may be inhibited by cimetidine co-administration and thereby increase the elimination half-life of ABZSX. In our study, a 2.6-fold prolongation of ABZSX elimination half-life was indeed observed after cimetidine co-administration. (7.4 ± 3.3 versus 19.0 ± 11.7 hours, respectively. \( P = 0.028 \)). Another factor that deserves further study is the possible metabolism of albendazole by CYP enzymes in the intestinal mucosa. Inter-individual variability in mucosal CYP enzyme activity is great and may thereby contribute to variability of ABZSX concentrations.

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REFERENCES


