Pharmacokinetics of Cefpirome Following Intravenous and Intramuscular Administration in Cow Calves


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ABSTRACT

Background: Cefpirome is a broad-spectrum semi synthetic $\beta$-lactamase resistant fourth generation cephalosporin. Looking to potential for clinical use, pharmacokinetics of cefpirome following intravenous and intramuscular administration (10 mg kg$^{-1}$) in cow calves was determined. Methods: Cefpirome concentration in plasma samples was determined by reverse-phase high performance liquid chromatography with mobile phase. The mobile phase was a mixture of 0.2 M sodium acetate (3.5%), acetonitrile (17.5%) and HPLC water (79%) with a pH of 5.1. Mobile phase was filtered by 0.45 µ filters and pumped into column at a flow rate of 1.0 mL min$^{-1}$ at ambient temperature. The effluent was monitored at 258 nm wavelength. Results: Following intravenous administration of the cefpirome in goats, volume of distribution at steady-state (Vd$_{ss}$), elimination half-life (t$_{1/2}$) and total body clearance (Cl$_{b}$) were reported 0.33±0.01 L kg$^{-1}$, 2.41±0.23 h and 2.36±0.18 mL min$^{-1}$ kg$^{-1}$, respectively. Following intramuscular administration of the drug, peak plasma concentration (C$_{max}$), elimination half-life (t$_{1/2}$), apparent volume of distribution (Vd$_{app}$), total body clearance (Cl$_{b}$), bioavailability (F) were 13.27±0.19 µg mL$^{-1}$, 3.61±0.12 h, 0.81±0.007 L kg$^{-1}$, 2.83±0.08 mL min$^{-1}$ kg$^{-1}$ and 61±1%, respectively. Conclusion: Pharmacokinetic – pharmacodynamics integration indicates cefpirome can be useful in cow calves at dose rate of 10 mg kg$^{-1}$ and repeated at interval of 12 h by intramuscular route.

Key words: Cefpirome, pharmacokinetics, intravenous, intramuscular, cow calves

INTRODUCTION

Cefpirome is a broad-spectrum semi synthetic $\beta$-lactamase resistant fourth generation cephalosporin used in severely ill patients in the intensive care, oncology and transplantation units. It has increased affinity for PBPs, reduce susceptibility to extended-spectrum $\beta$-lactamase and have ability to interfere with PBPs mediated cell wall synthesis ultimately leads to cell lysis. It has potent bactericidal activity against a broad range of gram-negative and gram-positive organisms, including Pseudomonas aeruginosa and methicillin susceptible Staphylococcus spp., H. hemophilus influenzae type B and many members of the Enterobacteriaceae family. The disposition kinetics of cefpirome have been investigated in rabbits, dogs, mice, rat and monkey, buffalo calves and goats. However, there is no information available on the pharmacokinetic of cefpirome in cow calves following intravenous and intramuscular routes of administration. Looking to potential for clinical use and possibility for species difference, the study was undertaken on pharmacokinetics of cefpirome following intravenous and intramuscular administration in cow calves.

MATERIALS AND METHODS

Experimental animals: The experiment was conducted on six healthy crossbred (Kankrej X H.F), weighing 65-105 kg. Each animal was housed in a separate pen and provided standard ration with ad libitum water. Cow calves were kept under constant observation for two weeks before the commencement of the experiment and subjected to clinical examination to exclude possibility of any diseases. The experimental protocol was approved by Institutional Animal Ethics Committee.

Drug and chemical: Cefpirome technical grade powder was procured from Orchid Pharma Ltd., Chennai. Cefpirome sulphaate powder (1 g Ceforth®;
Drug administration and sample collection: All six animals were randomly allocated to receive either an intravenous or intramuscular injection of Cefpirome at the dose rate of 10 mg kg\(^{-1}\). A washout period of two weeks was observed between treatments. An intravenous injection of Cefpirome was administered in the left jugular vein. Blood samples (3 mL) were collected through an intravenous catheter (Venflon, 22×0.9×25 mm) fixed in the contralateral jugular vein in glass test tubes, prior to injection and at 2, 5, 10, 15, 30 min and 1, 2, 4, 8, 12 and 18 h after intravenous administration. Following intramuscular injection of Cefpirome in the left deep gluteal muscle, blood samples (3 mL) were collected before administration and at 5, 10, 15, 30 min and 1, 2, 4, 8, 12, 18 and 24 h. Cow calves were monitored for any adverse reactions during the entire study period. Blood samples were centrifuged at 4116 g for 10 min at 4°C and plasma was transferred to cryo-vials (2 mL) and stored at -20°C. Samples were analyzed within 48 h to quantify cefpirome concentration using high performance liquid chromatography.

Analytical assay of cefpirome and pharmacokinetic analysis: Cefpirome concentration in plasma samples was determined by reverse-phase High Performance Liquid Chromatography (HPLC) after extraction, using reported assays\(^{9}\) with minor modifications. The High Performance Liquid Chromatography (HPLC) apparatus of Adept Cecil comprised of binary gradient delivery pump (model 4901), UV detector (model 4902) and reverse phase C18 column (4.6×100 mm ID). Pharmacokinetic data integration was performed using software "Power Stream" (Version 4.2). Plasma (500 µL) was deproteinized by addition of perchloric acid (0.8 M) and methanol (50:50) and vortexed for one minute. An aliquot of supernatant was collected in clean auto sampler vial. The mobile phase was a mixture of 0.2 M sodium acetate (3.5%), acetonitrile (17.5%) and HPLC water (79%). 0.2M acetic acid was used to adjust pH of 5.1. Mobile phase was filtered by 0.45 µ filters and pumped into column at a flow rate of 1.0 mL min\(^{-1}\) at ambient temperature. The effluent was monitored at 258 nm wavelength.

Calibration curve was prepared daily for drug concentration ranging from 0.8-200 µg mL\(^{-1}\). The assay was sensitive (LLOD: 0.8 µg mL\(^{-1}\)) and reproducible and linearity was observed from 0.8-200 µg mL\(^{-1}\) (\(r^2 = 0.99\)). Precision and accuracy were determined using Quality Control (QC) samples at concentrations 1.6, 50, 200 µg mL\(^{-1}\) (5 replicates each day). Intraday and interday co-efficients of variability for five QC samples were satisfactory with the relative deviations (RSD) of less than 6.54%. An absolute recovery of cefpirome was measured up to 96.30%. Various pharmacokinetic parameters were calculated from serum concentration of cefpirome using software PK solution (version 2.0). The bioavailability (F) was calculated using following equation:

\[ F(\%) = \frac{AUC (IM)}{AUC (IV)} \times \frac{DOSE (IV)}{DOSE (IM)} \]

Determination of minimal inhibitory concentrations of levofloxacin: Minimal inhibitory concentrations were determined against different organism Streptococcus pyogenes (ATCC:8668), Staphylococcus aureus (ATCC:25923), Escherichia coli (ATCC:25922), Salmonella typhimurium (ATCC:23564), Pseudomonas aeruginosa (ATCC:27853), Proteus mirabilis (N C1M :2241) and Bacillus subtilis (ATCC:9372). Which were procured form National Collection of Industrial Microorganism (N C1M), National Chemical Laboratory, Pune. The MIC of cefpirome was determined by micro broth dilution method in triplicates\(^{5}\).

Statistical analysis: Cefpirome serum concentration and pharmacokinetic parameters of different treatment groups were compared by students’ “t” test using SPSS software (version 12.0.1).

RESULTS Following single dose intravenous and intramuscular administration of cefpirome in the cow calves, adverse reactions were not observed. Pharmacokinetic parameters (Mean±SE) calculated for both route of drug administration have been depicted in Table 1.

Following intravenous administration of cefpirome, therapeutic concentration of cefpirome = 0.5 µg mL\(^{-1}\) was maintained in plasma from up to 8 h. Following intramuscular administration of the cefpirome, mean peak plasma drug concentration (\(C_{\text{max}}\)) of 13.27±0.19 µg mL\(^{-1}\) was achieved at 0.75 h (\(T_{\text{max}}\)) which declined rapidly to 8.27±0.14 µg mL\(^{-1}\) at 2 h. The drug concentration of 1.06±0.05 µg mL\(^{-1}\) in plasma was detected at 12 h and thereafter drug was not detected in plasma samples collected beyond 12 h post intramuscular administration in cow calves.

Following intravenous administration of the drug in cow calves, distribution half-life (\(t_{\frac{1}{2}}\)) ranged between 0.46 and 0.64 h with a mean of 0.53±0.03 h. The mean values of volume of distribution at steady-state (V\(_{\text{dss}}\)) were calculated to be 0.30±0.01 L kg\(^{-1}\). The elimination
Table 1: Pharmacokinetic parameters of cefpirome (10 mg kg⁻¹) following intravenous and intramuscular administration in cow calves (Mean±SE, n = 6)

<table>
<thead>
<tr>
<th>Pharmacokinetic parameters</th>
<th>Intravenous</th>
<th>Intramuscular</th>
</tr>
</thead>
<tbody>
<tr>
<td>K₁ (h⁻¹)</td>
<td>-</td>
<td>4.38±0.37</td>
</tr>
<tr>
<td>s (h⁻¹)</td>
<td>0.30±0.03</td>
<td>0.19±0.01</td>
</tr>
<tr>
<td>t₁/₂a (h)</td>
<td>-</td>
<td>0.16±0.01</td>
</tr>
<tr>
<td>t₁/₂e (h)</td>
<td>0.53±0.03</td>
<td>-</td>
</tr>
<tr>
<td>t₁/₂m (h)</td>
<td>2.41±0.23</td>
<td>3.61±0.12</td>
</tr>
<tr>
<td>Cₘ₉₁ (µg mL⁻¹)</td>
<td>-</td>
<td>12.37±0.19</td>
</tr>
<tr>
<td>Tₘ₉₁ (h)</td>
<td>-</td>
<td>0.75±0.00</td>
</tr>
<tr>
<td>AU C₀-₄₆₈ (µg h mL⁻¹)</td>
<td>96.69±1.05</td>
<td>58.96±0.71</td>
</tr>
<tr>
<td>Vdₘ₉₁ (L kg⁻¹)</td>
<td>0.30±0.01</td>
<td>-</td>
</tr>
<tr>
<td>Vdₘ₉₈₆ (L kg⁻¹)</td>
<td>0.81±0.07</td>
<td>-</td>
</tr>
<tr>
<td>Clₙ₉₁ (ml minG kg⁻¹)</td>
<td>2.36±0.18</td>
<td>2.83±0.08</td>
</tr>
<tr>
<td>M RT (h)</td>
<td>2.14±0.06</td>
<td>4.88±0.13</td>
</tr>
<tr>
<td>F (%)</td>
<td>-</td>
<td>61.00±1.00</td>
</tr>
</tbody>
</table>

K₁: Absorption rate constant, s: Elimination rate constant, t₁/₂a: Half-life of distribution phases, t₁/₂e: Elimination half-life, t₁/₂aₙₙₙₙ: Absorption half-life, AU C₀-₄₆₈: Total area under plasma drug concentration-time curve, Vdₘ₉₁: Volume of distribution based on area, Vdₘ₉₈₆: Volume of distribution at steady state, Clₙ₉₁: Total body clearance, M RT: Mean residence time, Cₘ₉₁: Maximum drug concentration, Tₘ₉₁: Time of maximum concentration observed in plasma and F: Bioavailability

Half-life (t₀.₅) ranged from 1.62 to 3.12 h with a mean of 2.41±0.23 h. Total body clearance (Cₐₙ) of the drug was 2.36±0.18 mL min⁻¹ kg⁻¹ with a mean residence time (M RT) of 2.14±0.06 h. Following intramuscular administration of the drug, absorption (t₁/₂a) and elimination half-life (t₁/₂e) were 0.16±0.01 and 3.61±0.12 h, respectively. The mean apparent volume of distribution (Vdₘ₉₁) was 0.30±0.01 L kg⁻¹ and M RT was 2.14±0.06 h. Bioavailability of the drug following intramuscular administration ranged from 59-64% with an average of 61±1%.

The minimal inhibitory concentration of cefpirome were 0.13, 0.25, 0.5, 0.5, 1, 2 and 8 µg mL⁻¹ for E. coli, Salmonella typhimurium, Staphylococcus aureus, B. subtilis, Streptococcus pyogenes, P. aeruginosa and Proteus mirabilis, respectively.

**DISCUSSION**

Following single dose intravenous administration, elimination half-life (t₁/₂e: 2.41±0.23 h) of cefpirome observed in cow calves is in agreement to the elimination half-life of 2.14±0.02 h and 2.12±0.14 h reported in buffalo calves and goats6,10. However, shorter elimination half-life of 0.19 h in mouse, 1.05 h in dogs, 1.17 h in monkeys and 1.48 h in rabbits have been reported.

The mean residence time calculated following single dose intravenous administration was 2.14±0.06 h in cow calves, which is in agreement with reported values of 2.89±0.01 and 2.72±0.11 h in buffalo calves and goats6,10. However, it was observed that cefpirome principally eliminated by the kidney and 80-90% of the administered drug was recovered as unchanged form in the urine6. Body clearance (2.36±0.18 mL min⁻¹ kg⁻¹) of cefpirome in cow calves following intravenous route of administration in present study found to be higher than clearance values of 2.00±0.05 mL min⁻¹ kg⁻¹ in buffalo calves6, 2.13±0.05 mL min⁻¹ kg⁻¹ in goats and 3.2 mL min⁻¹ kg⁻¹ in dogs6 reported following intravenous administration of cefpirome. The low value of mean volume of distribution at steady state (Vdₘ₉₁: 33.3±0.01 L kg⁻¹) in cow calves following cefpirome intravenous administration indicated the limited distribution of drug into various body fluids and tissues. Similar low value of Vdₘ₉₁ (0.40±0.004 and 0.35±0.01 L kg⁻¹) have been reported in buffalo calves and goats6,10. In addition to this limited distribution of other cephalosporins like cefpirome was also reported in goat and sheep12,13,14,15.

Following intramuscular administration of cefpirome in cow calves, the peak plasma concentration (Cₘ₉₁) of 13.27±0.19 µg mL⁻¹ was observed at 0.75 h (Tₘ₉₁). Similarly, Cₘ₉₁ of 9.04±0.5 µg mL⁻¹ at 0.5 h in buffalo calves6, 17.1 µg mL⁻¹ at 0.42 h in monkeys, 9.2 µg mL⁻¹ at 0.48 h in rats and 15.4 µg mL⁻¹ at 0.70 h in dogs13 and 10.97±0.34 µg mL⁻¹ in goats have been reported. Elimination half-life (t₁/₂e: 3.61±0.12 h) obtained in present study is higher than reported elimination half-life of 2.09±0.08 h in goats13, 2.39±0.05 h in buffalo calves6, 1.38 h in dogs and 1.23 h in monkeys13. Clearance (2.83±0.08 mL min⁻¹ kg⁻¹) of the drug observed following intramuscular administration is similar to that reported in goat (2.88±0.10 mL min⁻¹ kg⁻¹)6. Moreover, value of mean apparent volume of distribution (Vdₘ₉₁: 0.81±0.07 L kg⁻¹) indicated good distribution of drugs in body tissues following intramuscular administration of cefpirome in cow calves. Value of Vdₘ₉₁ for cow calves in present study is higher than reported values of 0.42±0.01 L kg⁻¹ in buffalo calves6 and 0.52±0.02 L kg⁻¹ in goats6. Systemic bioavailability (61±1%) following intramuscular administration of cefpirome in cow calves is higher than 35.3±3.1% reported in buffalo calves6 and in less than that reported in goats (75±4%)6. High systemic bioavailability and maintenance of therapeutic concentration up to 12 h following intramuscular injection suggests that cefpirome is suitable for intramuscular administration for the treatment for systemic bacterial infections in cow calves.

For β-lactam antibiotics, time for which serum drug concentration exceeds the MIC (T>MIC) of pathogens is considered as primary determinant of antibacterial efficacy16. In addition to this, for β-lactam antibiotics maximum killing was seen when the time above MIC is at least 70% of the dosing interval17. Minimum inhibitory concentration obtain for cefpirome sensitive bacteria like E. coli, Salmonella typhimurium, Staphylococcus aureus and B. subtilis, range from 0.1 to 0.5 µg mL⁻¹ and similar finding were also reported by other authors16,18. Integrating the cefpirome pharmacokinetic data and the MIC values a cefpirome, an intravenously or
intramuscular dose of 10 mg kg\(^{-1}\) repeated at 12 h interval is sufficient to maintain plasma concentration of the drug above the MIC. However, for Pseudomonas aeruginosa (whose MIC value is 2 µg mL\(^{-1}\)), a cefpirome dose of 10 mg kg\(^{-1}\) is sufficient to maintain plasma concentration of the drug above the MIC when it is administered intravenously or intramuscularly at 8 h interval.

**CONCLUSIONS**

Pharmacokinetic-pharmacodynamics integration indicates cefpirome can be useful in cow calves at dose rate of 10 mg kg\(^{-1}\) and repeated at interval of 12 h by intramuscular route.

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