Bactericidal action of PD127,391, an enhanced spectrum quinolone

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Summary. The 4-quinolone PD127,391 displays a biphasic effect on Escherichia coli, Staphylococcus aureus and S. epidermidis in nutrient broth. It is as active as ciprofloxacin in terms of its optimum bactericidal concentration against E. coli. However, against staphylococci it is six times as active as ciprofloxacin or any other 4-quinolone previously investigated. Although protein and RNA synthesis are not required for bactericidal activity, cell division is essential.

Introduction

PD127,391 is an enhanced spectrum, fluorinated 4-quinolone that exhibits low minimum inhibitory concentrations (MICs) and minimum bactericidal concentrations (MBCs) against a wide range of gram-negative and gram-positive clinical isolates. The ability of the 4-quinolones to kill bacteria varies under different conditions. Protein synthesis, RNA synthesis and cell division are essential for the bactericidal activity of older 4-quinolones such as nalidixic acid. One explanation is that these kill bacteria by a mechanism, termed A, that requires protein synthesis, RNA synthesis and cell division. However, all the modern fluorinated 4-quinolones that have been investigated are active against non-dividing bacteria probably because of a bactericidal mechanism other than A.

The fluorinated 4-quinolones can be divided into two groups. In the first, which includes ciprofloxacin, ofloxacin, DR-3355, lomefloxacin, pefloxacin and floxacin, the second bactericidal mechanism, termed B, does not require bacterial protein and RNA synthesis. The second group contains norfloxacin and enoxacin which are bactericidal against non-dividing bacteria but require protein and RNA synthesis for their additional mechanism, first found in norfloxacin and termed C.

Determination of the MIC and MBC does not provide any information about the conditions required for the killing of bacteria by an antibacterial agent. Furthermore, these assays do not provide information on the optimum bactericidal concentration (OBC) at which killing activity is greatest. Therefore, we have studied the conditions required for PD127,391 to kill Escherichia coli, Staphylococcus aureus and S. epidermidis.

Materials and methods

Bacterial strains

Laboratory strains E. coli KL16, S. aureus E3T and S. epidermidis SK360 were used in this study. These strains were chosen because of their consistent use in previous evaluations of the bactericidal mechanisms of the 4-quinolones. The strains were kept on drug-free nutrient agar and subcultured every 10 days. Colonies taken from drug-free nutrient agar were used to prepare the overnight cultures used in these experiments.

Antibacterial preparation

PD127,391 (Parke-Davis, UK), chloramphenicol (Parke-Davis, UK) and rifampicin (Ciba, UK) were dissolved in sterile distilled water for incorporation in test media.

Determination of antibacterial effects of PD127,391

The killing activity of PD127,391 at drug concentrations of 0.005–9 mg/L was determined in nutrient broth (Oxoid) at 37°C over a 3-h period. Survival was estimated by serial dilution in nutrient broth followed by viable counts on nutrient agar as previously described. The rate of kill of bacteria exposed to PD127,391 in nutrient broth or phosphate-buffered saline (PBS) was measured at 30-min intervals over a 4-h period by viable counts on nutrient agar as previously described.

Results

The bactericidal activity of PD127,391 at concentrations of 0.005–9 mg/L against E. coli, S. aureus and S. epidermidis in nutrient broth over 3 h showed...
a biphasic effect characteristic of the bactericidal activity of the 4-quinolones (fig. 1). The bactericidal activity increased until the OBC was reached. This was 0.15 mg/L for *E. coli* and 0.5 mg/L for both staphylococcal strains. At higher concentrations, the drug became less bactericidal. At its OBC, PD127,391 was still significantly bactericidal against *E. coli* in nutrient broth even in the presence of a bacteriostatic concentration of chloramphenicol, which inhibits protein synthesis (fig. 2), or rifampicin, which inhibits RNA synthesis (fig. 3). The bactericidal activity of PD127,391 in the presence of chloramphenicol or rifampicin did not derive from residual protein or RNA synthesis because PD127,391 was still bactericidal when it was added to *E. coli* that had been pre-incubated for 60 min with either drug (figs. 2 and 3). However, when the two drugs were added together, some of the bactericidal activity of PD127,391 seemed to result from residual protein or RNA synthesis because the lethality of the 4-quinolone was reduced when it was added to the mixture at 60 min (figs. 2 and 3).

It can be seen from figs. 4 and 5 that the addition of a bacteriostatic concentration of chloramphenicol did not completely abolish the bactericidal activity of PD127,391 at its OBC against *S. aureus* or *S. epidermidis*. The bactericidal activity did not result from residual protein or RNA synthesis because pre-incubation of the staphylococci with chloramphenicol did not reduce the bactericidal activity of the 4-quinolone (figs. 4 and 5). Hence PD127,391 seems to exert mechanism B, which does not require bacterial protein synthesis or RNA synthesis, against both *E. coli* and the staphylococci. Furthermore, the abolition of protein synthesis or RNA synthesis significantly reduced the bactericidal activity of PD127,391 against all three strains which confirms that the 4-quinolone possesses mechanism A.

The bactericidal activity of PD127,391 against *E. coli*, *S. aureus* and *S. epidermidis* was then investigated in PBS. It can be seen from fig. 6 that the 4-quinolone, at its OBC, was not significantly bactericidal against *E. coli* or *S. epidermidis* under

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**Fig. 1.** Survival of *E. coli* (▲—▲), *S. aureus* E3T (○—○) and *S. epidermidis* SK360 (●—●) after exposure to PD127,391 in nutrient broth for 3 h at 37°C.

**Fig. 2.** Survival of *E. coli* KL16 in nutrient broth at 37°C with PD127,391 0.15 mg/L (○—○), PD127,391 0.15 mg/L + chloramphenicol 20 mg/L (■—■), chloramphenicol 20 mg/L + PD127,391 0.15 mg/L at 60 min (▲—▲) or chloramphenicol 20 mg/L (●—●).
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Fig. 3. Survival of *E. coli* KL16 in nutrient broth at 37°C with PD127,391 0.15 mg/L (○—○), PD127,391 0.15 mg/L + rifampicin 160 mg/L (■—■), rifampicin 160 mg/L + PD127,391 0.15 mg/L at 60 min (○—○) or rifampicin 160 mg/L (△—△).

Fig. 4. Survival of *S. aureus* E3T in nutrient broth at 37°C with PD127,391 0.5 mg/L (○—○), PD127,391 0.5 mg/L + chloramphenicol 20 mg/L (■—■), chloramphenicol 20 mg/L + PD127,391 0.5 mg/L at 60 min (○—○) or chloramphenicol 20 mg/L (△—△).

Fig. 5. Survival of *S. epidermidis* SK360 in nutrient broth at 37°C, with PD127,391 0.5 mg/L (■—■), PD127,391 0.5 mg/L + chloramphenicol 20 mg/L (○—○) chloramphenicol 20 mg/L + PD127,391 0.5 mg/L at 60 min (△—△), or chloramphenicol 20 mg/L (○—○).

these conditions over a 4-h period. PD127,391 was slightly bactericidal against *S. aureus* in PBS (fig. 6) but the amount of kill was considerably less than that observed in nutrient broth containing chloramphenicol (fig. 4). Hence, bacterial cell division appears essential for the lethality of PD127,391.

Discussion

The bactericidal activity of PD127,391 against *E. coli*, *S. aureus* and *S. epidermidis* in nutrient broth showed a biphasic effect, common to other 4-quinolones. The OBC of PD127,391 against *E. coli* (0.15 mg/L) is the same as that reported for ciprofloxacin and lower than reported for DR-3355 (0.5 mg/L), ofloxacin (0.9 mg/L), norfloxacin, lomefloxacin, pefloxacin, fleroxacin (all 1.5 mg/L), and enoxacin (3–5 mg/L). The OBC of PD127,391 against both *S. aureus* and *S. epidermidis* was 0.5 mg/L. This is significantly lower than that reported for the other 4-quinolones investigated. For example, the OBCs of the 4-quinolones with the most activity against staphylococci, DR-3355 and ciprofloxacin, are 3 mg/L for *S. aureus* and *S. epidermidis*. This is six times
higher than that of PD127,391 against these strains. Hence, PD127,391 would appear to have an enhanced spectrum in terms of its bactericidal activity as well as its bacteriostatic activity.²

PD127,391, like the other modern fluorinated 4-quinolones displays a bactericidal mechanism additional to mechanism A. This appears to be novel because cell division was essential for the lethal action of PD127,391. This contrasts with the other fluoroquinolones, all of which are active against non-dividing bacteria.³, ⁴, ⁷, ¹⁰ We propose that this mechanism be termed B, because it is similar to mechanism B² in that it does not require protein synthesis or RNA synthesis to exert its lethal action.

In conclusion, PD127,391 seems to merit further investigation as, in contrast to the clinically available fluoroquinolones, it is almost as bactericidal against staphylococci as it is against E. coli. This enhanced activity against staphylococci may be significant because, at present, the 4-quinolones are not always successful in resolving staphylococcal infection and, indeed, resistance can develop during therapy.¹⁴

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REFERENCES