The Pharmacokinetic and Pharmacodynamic Profile of Tigecycline

Alison K. Meagher,[1,a] Paul G. Ambrose,[2] Thaddeus H. Grasela,[1] and Evelyn J. Ellis-Grosse[3]

[1]Cognigen Corporation, Buffalo, and [2]Institute for Clinical Pharmacodynamics/Ordway Research Institute, Albany, New York; [3]Wyeth Research, Collegeville, Pennsylvania

Tigecycline, a first-in-class expanded-spectrum antimicrobial agent, has demonstrated efficacy in the treatment of complicated intra-abdominal and skin and skin-structure infections. This new antibiotic is available as an intravenous formulation and exhibits linear pharmacokinetics. It is rapidly distributed and has a large volume of distribution, indicating extensive tissue penetration. After a 100-milligram loading dose, followed by 50 milligrams every 12 h, the steady-state maximum concentration in serum after a 1-h infusion is ~0.6 μg/mL, the 24-h steady-state area under the concentration–time curve is ~5–6 μg · h/mL, and the terminal elimination half-life is ~40 h. The major route of elimination of tigecycline is through the feces, primarily as unchanged drug. The pharmacokinetic profile is not affected by severe or end-stage renal disease, nor is it significantly altered by hemodialysis. The pharmacokinetics of tigecycline are also not affected by food, although tolerability is increased if the drug is administered following a meal.

Glycylcyclines are a novel class of antimicrobial agents, and tigecycline (figure 1) is the first of the glycylcyclines to reach the final stage of clinical development. Tigecycline inhibits translation of bacterial proteins through its action on the 30S ribosomal subunit and circumvents resistance mechanisms, primarily ribosomal protection and efflux of the antibiotic, thus retaining activity against both tetracycline- and minocycline-resistant bacterial strains [1–3]. This new antimicrobial agent has demonstrated broad-spectrum in vitro and in vivo activity against a wide spectrum of aerobic and anaerobic gram-positive and gram-negative bacteria, including resistant strains. The activity of tigecycline against methicillin-resistant *Staphylococcus aureus,* penicillin-resistant *Streptococcus pneumoniae,* and vancomycin-resistant enterococci is impressive, and the susceptibility of most genera of Enterobacteriaceae, including extended-spectrum β-lactamase–producing and –nonproducing strains, and most strains of *Bacteroides fragilis* is notable [1–9]. Encouraging results have been observed with tigecycline in the treatment of hospitalized patients with severe complicated skin and skin-structure infections and complicated intra-abdominal infections [10–13]. Tigecycline has the potential to be an option for monotherapy in treating patients with these serious infectious diseases.

The importance of the pharmacokinetics of antimicrobial agents is well established and serves as the foundation for the identification of critical pharmacokinetic and pharmacodynamic exposure response relationships in in vitro, animal, and human systems. Here, we review the initial pharmacokinetic profile of tigecycline, with an emphasis on pharmacokinetics established in healthy subjects, as well as relevant in vitro and animal pharmacokinetic and pharmacodynamic studies.

PHARMACOKINETICS IN EXPERIMENTAL ANIMALS AND IN VITRO MODELS

The pharmacokinetic properties of tigecycline have been studied in several animal species. Overall, the pharmacokinetics in animals is characterized by a low

[a] Present affiliation: Department of Clinical Research Services, Roswell Park Cancer Institute, Buffalo, New York.

Reprints or correspondence: Dr. Alison K. Meagher, Dept. of Clinical Research Services, Roswell Park Cancer Institute, Elm and Carlton St., Buffalo, NY 14263 (alison.meagher@roswellpark.org).

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total clearance (CL_T), a large apparent volume of distribution at steady state (V_{ss}), and a long elimination half-life ($t_{1/2}$). In all studies, tigecycline was administered as an intravenous infusion because of low bioavailability following oral administration.

A tissue distribution study with [^{14}C]tigecycline and tissue dissection in rats revealed peak radioactivity concentrations at the end of a 30-min infusion [14]. Radioactivity was well distributed to most tissues, with the highest overall exposure observed in bone, liver, spleen, and kidney. In these tissues, the ratio of the area under the concentration–time curve (AUC) in tissue to the AUC in plasma was >8, with the AUC value in bone ~250-fold higher than that in plasma. Tissue exposure in the lung, as measured by the AUC value, was >4 times higher than the exposure in plasma. All tissues had detectable radioactivity 1 week after dosing, and long-term radioactivity was observed in bone, with an estimated $t_{1/2}$ >200 h. Chelation to calcium and adherence to bone is well documented for members of the tetracycline class of antibiotics [15], and so it is anticipated to be true for members of the glycylcycline class.

In vitro binding of tigecycline was evaluated in human plasma by both ultrafiltration and ultracentrifugation [16]. Increased protein binding was observed with increasing tigecycline concentrations. The mechanism for the concentration-dependent binding is unknown to date but may be attributable to the formation of metal ion complexes, as has been documented with tetracycline [17–19]. At tigecycline concentrations of 0.1 and 1.0 μg/mL, protein binding was 71% and 87%, respectively, as determined by use of an ultrafiltration technique, and was 73% and 79%, respectively, as determined by use of ultracentrifugation. As a point of reference, the mean ($\pm$SD) maximum steady-state serum concentration of tigecycline from a phase 3 trial of hospitalized patients with complicated skin and skin-structure infections was 0.63 $\pm$ 0.28 μg/mL [20].

The metabolic disposition and mass balance of tigecycline has been evaluated in rats and dogs by using radiolabeled tigecycline [21]. The predominant compound recovered from both species was parent drug, followed by an epimer of tigecycline and a metabolite resulting from amide hydrolysis of the t-butylaminoacetylamino side chain. Mass balance and excretion studies conducted in rats and dogs revealed that fecal elimination is the primary route of excretion (~50%), which is suggestive of biliary excretion. Approximately 35% of recovered tigecycline was excreted in urine as unchanged drug in these studies.

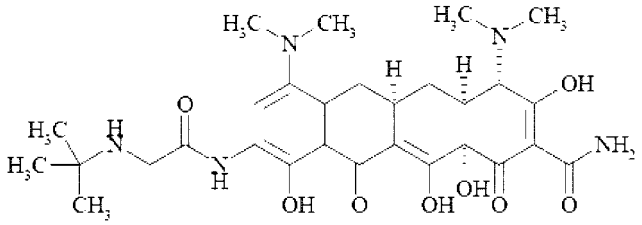

Figure 1. Molecular structure of tigecycline (molecular mass, 585 Da)

ANIMAL PHARMACOKINETIC AND PHARMACODYNAMIC MODELS

The interrelationship between the pharmacokinetics and pharmacodynamics of antimicrobial agents has become increasingly important. Data from in vitro and in vivo infection models, including dose fractionation studies, can examine the effect of a broad range of drug exposures on bacteria of interest. The information derived from these studies can be integrated with data from human clinical trials to define the pharmacokinetic/pharmacodynamic target and the magnitude of that target associated with optimal microbiological and clinical outcomes. Several studies have successfully demonstrated the concordance among pharmacokinetic/pharmacodynamic targets derived from nonclinical models of infection with those from clinical data [22–26].

In vitro studies have shown that tigecycline exhibits a time-dependent pattern of bactericidal activity against several gram-positive and -negative organisms, including *S. pneumoniae, Haemophilus influenzae,* and *Neisseria gonorrhoeae* [3]. The pharmacokinetic/pharmacodynamic index often associated with drugs that display a time-dependent pattern of killing, such as the β-lactams, is the time above the MIC for the organism. For antimicrobial agents with moderate to prolonged postantibiotic effects, however, the time of exposure is less important, and the ratio of AUC to MIC is the important determinant of efficacy [27]. As a result of the substantial postantibiotic effects associated with the tetracycline antibiotics, for example, the ratio of AUC to MIC is the pharmacokinetic/pharmacodynamic index characteristically associated with this class of drugs. Although there is a relative lack of data with older antibiotics within the tetracycline class, the ratio of AUC to MIC is the pharmacokinetic/pharmacodynamic index that has been documented to best predict the in vivo activity of doxycycline against *S. pneumoniae* [28].

By use of a neutropenic mouse thigh-infection model, van Ogtrop et al. [29] conducted a pharmacodynamic study to identify and characterize the pharmacokinetic/pharmacodynamic indices required for optimal in vivo activity and the efficacy of tigecycline against selected gram-negative and gram-positive organisms. The in vivo antibacterial activity of tigecycline against several isolates of common human pathogens (e.g., *S. pneumoniae, S. aureus, Escherichia coli,* and *Klebsiella pneumoniae*) were determined, and the postantibiotic effect was evaluated. Single-dose pharmacokinetics of tigecycline were characterized in serum obtained from thigh-infected mice after

administration of subcutaneous intravenous doses (0.75–192 mg/kg/day), with most doses given on a twice-daily dosing schedule. Pharmacokinetic parameters of tigecycline, including $t_{1/2}$, maximum serum concentration (C_{max}), apparent volume of distribution (V_D), and AUC, were determined.

The evaluation of the pharmacokinetics of tigecycline over this very broad dosage range in mice revealed nonlinear kinetics and $t_{1/2}$ values ranging from 1.05 h at the lowest dose of 3 mg/kg up to 2.34 h at the highest dose of 48 mg/kg. The AUC from time zero to infinity ($AUC_{0-\infty}$) ranged from 0.68–36.5 μg·h/mL, and the C_{max} ranged from 0.42–11.1 μg/mL. Serum protein binding in mice was determined to be 59%.

The in vivo postantibiotic effect of tigecycline against *S. pneumoniae* ATCC 10813 and *E. coli* ATCC 25922 was determined following infection and administration of a 3-mg/kg dose. The postantibiotic effect was found to be 8.9 and 4.9 h against *S. pneumoniae* and *E. coli,* respectively. Study results indicated that tigecycline exhibited time-dependent in vivo antimicrobial activity. Time above a certain factor (range, 0.5–4) times the MIC for 5 of the 6 organism-drug combinations studied was the predictor of drug efficacy. However, because of the relatively long $t_{1/2}$ and the extended postantibiotic effect of tigecycline, the AUC was also reasonably predictive, with slightly lower r^2 values (figure 2).

Several limitations of this study should be considered when translating these data to humans. The analysis was somewhat hampered by the nonlinearity of the pharmacokinetics in mice, which became important for the lower doses, for which pharmacokinetic parameters had to be extrapolated. In contrast, tigecycline has exhibited linear kinetics in humans [16]. Furthermore, tigecycline has a relatively long $t_{1/2}$ in humans (~40 h), compared with a $t_{1/2}$ of ~1–2 h in mice. Other points to consider include the fact that animal infection models such as this do not account for host factors, such as neutrophils. The extensive distribution of tigecycline into tissues suggests that serum concentrations may not be reflective of the drug concentration at the clinical site of infection.

In addition, the methodology for susceptibility testing of tigecycline has been modified since the time this study was done. The approved testing methodology for broth dilution tests with tigecycline now requires the use of fresh Mueller-Hinton broth (media prepared and used within 12 h) for aerobic organisms, to minimize the oxidative degradation of tigecycline and standardize testing conditions. Organisms retested by the approved methodology may have MICs that are 1 dilution lower than previously reported values. Interpretation of pharmacokinetic/pharmacodynamic indices relating MIC values determined by nonreference methods must be viewed with caution. Therefore, the long postantibiotic effect of tigecycline, in combination with the relatively long $t_{1/2}$ of the drug in humans, would suggest that the ratio of AUC to MIC is likely to be predictive of the clinical and microbiological efficacy of tigecycline. Further animal studies, possibly simulating human pharmacokinetics data, and evaluation of human pharmacokinetics in conjunction with results from clinical trials will more fully characterize the optimal pharmacokinetic/pharmacodynamic index.

HUMAN PHARMACOKINETICS

The pharmacokinetics of tigecycline, including metabolism and mass balance studies, have been evaluated in healthy subjects and in patients with complicated skin and skin-structure infections in a clinical trials program [16, 20, 21, 30–34]. A robust population pharmacokinetics model that will more fully describe the disposition of tigecycline is in development and will be further applied to characterize exposure-response relationships for patients in the phase 2 and phase 3 clinical development programs.

The metabolism and excretion of [^{14}C]tigecycline in human volunteers has been evaluated following intravenous adminis-

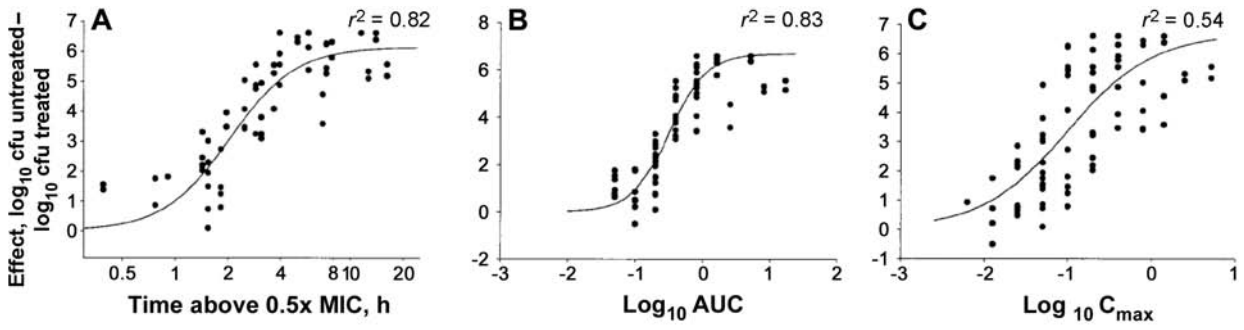

Figure 2. Relationship between 3 pharmacokinetic/pharmacodynamic indices and therapeutic efficacy of tigecycline (free drug) against *Streptococcus pneumoniae* 1199 in the neutropenic mouse thigh muscle infection model. For this organism, the correlation coefficient (r^2) was highest for the relationship between the change in $\log_{10}$ maximum concentration (C_{max}) in colony-forming units per thigh and the percentage of time above 0.5× the MIC, with a comparable r^2 value for $\log_{10}$ area under the concentration-time curve (AUC).

tration of a single, unlabeled 100-mg dose followed by five 50-mg doses every 12 h, with the last dose administered as a radiolabeled formulation [21]. Tigecycline circulates primarily as unchanged drug, and its major route of elimination is through feces, likely via biliary excretion. Feces contained 59% of the radioactive dose, and urine contained 32% of the radioactive dose, primarily as parent drug. Conjugated metabolites of tigecycline and its epimer and *N*-acetyl-9-aminominocycline were the major metabolites detected in human serum, urine, and feces. The glucuronide conjugates accounted for 5%–20% of serum radioactivity, and ~4% and 5% of the dose was excreted as conjugates in urine and feces, respectively. In contrast to these findings in humans, significant metabolism and conjugated metabolites were not observed in animals.

The preliminary pharmacokinetic profile of tigecycline in humans was established in a phase 1 ascending single-dose study in healthy, predominately white, males [31]. Tigecycline was administered by intravenous infusion in all human studies because of poor oral absorption. Sixty-eight subjects received tigecycline intravenously, in doses ranging from 12.5 to 300 mg, under both fasting and fed conditions, with most doses infused over 1 h. The 200- and 300-mg doses were also administered as 4-h infusions to evaluate the safety and tolerability of extended infusion durations. In addition, the 200-mg dose was administered to fasting subjects who received pretreatment with ondansetron. Full pharmacokinetic profiles of tigecycline were determined.

Tigecycline was extensively distributed, as demonstrated by a V_D ranging from 7 to 17 L/kg. The mean C_{max} and AUC increased proportionately with dose within the tested range. After a 1-h infusion, the C_{max} increased from 0.11 to 2.80 μg/mL, and the AUC increased from 0.75 to 17.9 μg·h/mL for doses ranging from 12.5 to 300 mg, respectively. The mean clearance ranged from 0.2 to 0.3 L/h/kg across all dose groups, with <13% excreted in the urine as unchanged drug. Tigecycline had a $t_{1/2}$ of ~40–60 h in subjects receiving doses of 200 and 300 mg. The pharmacokinetics of tigecycline were not significantly affected by food; however, the tolerability of the drug was improved when doses were administered following a meal. A similar study conducted in healthy Japanese male subjects revealed comparable pharmacokinetic profiles for tigecycline doses ranging from 25 to 150 mg [33].

Effects of age and sex were evaluated in a single-dose study of tigecycline at 100 mg infused for 1 h in healthy young (18–50 years), young elderly (65–75 years), and elderly (>75 years) men and women [32]. The mean AUC value across the 3 groups of women was ~5 μg·h/mL. The lowest AUC values were noted in men <50 years of age (mean, 4.2 μg·h/mL), and the highest were found in men >75 years of age (mean, 5.8 μg·h/mL), but these differences were not statistically significant. The mean C_{max} across all age and sex groups was 0.85 and 1.0 μg/mL, and the mean weight-adjusted V_D was ~5.8 and 6.2 L/kg for women and men, respectively. Results from this study did not reveal any significant differences in pharmacokinetic parameters of tigecycline based on age and sex and indicated that dosage adjustment on the basis of these characteristics is not necessary.

The effect of severe renal impairment (CL_{CR} of ≤30 mL/min) and end-stage renal disease (ESRD) on the pharmacokinetics of tigecycline were evaluated [34]. Tigecycline was administered as a single 100-mg intravenous dose infused over 1 h. Subjects with ESRD who were undergoing hemodialysis received study drug either 2 h before dialysis or 4 h after dialysis to determine whether tigecycline, which has a molecular mass of 586 Da, is efficiently removed by hemodialysis. The mean tigecycline C_{max} was 60% higher in subjects with ESRD than in age-matched, healthy subjects (0.96 vs. 0.60 μg/mL). The AUC, however, was only 20% higher in subjects with ESRD (4.04 vs. 3.33 μg·h/mL). Interestingly, subjects with severe renal impairment had C_{max} values similar to those of healthy subjects, but the mean AUC values in this group were 40% higher (4.76 μg·h/mL). None of these differences was statistically significant, and the higher exposures did not result in an increase in adverse events. The pharmacokinetic profile of subjects who received tigecycline either prior to or after dialysis did not differ, indicating that tigecycline is not significantly cleared by hemodialysis. These results suggest that tigecycline dosing does not require adjustment for patients with renal impairment, and that patients undergoing hemodialysis can receive tigecycline either before or after a dialysis session.

Results of a pharmacokinetic analysis of tigecycline after single and multiple doses in healthy subjects were recently published [16]. Data from subjects enrolled in 3 phase 1 safety and tolerability studies were explored: an ascending single-dose study, an ascending multiple-dose study, and a study of variable volumes and infusion rates. Subjects in the single-dose study received tigecycline doses ranging from 12.5 to 300 mg, as previously described [31]. In the ascending multiple-dose trial, male subjects received 1-h intravenous infusions of tigecycline in doses of 25, 50, and 100 mg administered every 12 h for 9 days, with a single dose on day 10. The study of infusion time and volume was designed to compare the safety and tolerability of tigecycline administered intravenously in 250 mL of saline over 60 min, in 100 mL of saline over 60 min, or in 100 mL of saline over 30 min, after an initial loading dose of 100 mg followed by 50 mg of tigecycline every 12 h for 5 days. This analysis established that tigecycline exhibits linear kinetics, as indicated by the absence of significant differences in systemic clearance (range, 0.2–0.3 L/h/kg) and $t_{1/2}$ (range, 37–67 h). A V_D of 7–10 L/kg revealed extensive tissue distribution. Tigecycline was found to be safe and well tolerated in the dose ranges examined. In addition, differences in rates of adverse events between 30-min and 60-min infusions were not detected,

suggesting that tigecycline can be safely administered with the briefer infusion.

A meta-analysis using data from 174 subjects in five completed phase 1 studies sought to provide a comprehensive description of the pharmacokinetics of tigecycline in healthy volunteers and to explore the relationships between the pharmacokinetic parameters and certain patient descriptors [30]. The 5 studies included an ascending single-dose study [31], an ascending multiple-dose study, an age and sex effects study [32], a renal impairment study [34], and an infusion time and administration volume study [16].

Plasma and urine concentration data were analyzed by noncompartmental methods. Nonparametric tests (Kruskal-Wallis) were used to explore the relationships between pharmacokinetic parameters and patient descriptors stratified by dose levels, duration of infusion, and treatment day. A significance level of 0.01 was used to define statistical significance, as determined with SAS software (version 8.2; SAS).

The mean (±SD) age of the 174 subjects in the study population was 40.1 ± 17.5 years (range, 19–84 years), and the mean weight was 75.8 ± 12.5 kg (range, 49.6–186 kg). Creatinine clearance, as calculated using the method of Cockcroft and Gault [35], ranged from 4.9 to 186 mL/min. Approximately 14% of the population were female ($n = 25$); 69.5% were white ($n = 121$), 26.4% were black ($n = 46$), and 4% were classified as other ($n = 7$).

Mean pharmacokinetic parameters for single- and multiple-dose studies are listed in table 1. As shown in figure 3, the plasma concentration-time profile was characterized by a steep decline in the distribution phase during the first 2 h after administration of tigecycline, followed by a long terminal-phase $t_{1/2}$. Steady-state concentrations appeared to be reached in ~3 days. To avoid any potential confounding of results on the basis of age and renal function, the following 4 populations of subjects were evaluated for each parameter: total subject population ($n = 144$); healthy subjects aged 18–50 years with normal renal function ($n = 99$); elderly subjects (young elderly subjects, aged 51–75 years [$n = 19$]; elderly subjects, aged >75 years [$n = 12$]); and subjects with severe renal impairment ($n = 6$) or ESRD ($n = 8$).

Maximum tigecycline concentrations ranged from 0.11 μg/mL at the 12.5-mg dose to 2.82 μg/mL at the 300-mg dose on day 1 following a 1-h infusion. An ~30% increase in C_{max} was noted on day 10 for the 13 subjects who contributed values on both day 1 and day 10. A strong relationship between C_{max} and weight was observed; however, normalizing the parameter by body weight did not completely explain this association. Thus, this relationship was explored by comparing populations with similar weight ranges. There was a trend for female subjects ($n = 8$) to experience a higher dose-normalized C_{max} than did male subjects ($n = 67$) within the same weight range, but differences in C_{max} based on race were not detected. Despite a similar distribution of weight across the three age categories, a statistically significant difference in dose normalized C_{max} versus age category ($P < .001$) was found at the 100-mg dose on day 1, with elderly subjects >75 years old experiencing a higher normalized C_{max} (~20% greater) than that of the young healthy population.

The AUC for tigecycline was evaluated by using $AUC_{0-\infty}$ on day 1 and the steady-state AUC on day 10. AUC values on days 1 and 10 for the same subject were not available for direct comparison. There was a strong relationship between AUC and

Table 1. Values for pharmacokinetic parameters for subjects in 5 phase 1 trials.

Dose regimen, parameter	Tigecycline dose, mg						
	12.5	25	50	75	100	200	300
Single dose							
C_{max},[a] μg/mL	0.11 ± 0.01	0.25 ± 0.06	0.38 ± 0.06	0.57 ± 0.08	0.93 ± 0.22	1.79 ± 0.53	2.82 ± 0.48
V_{ss}, L/kg	2.8 ± 0.95	6.4 ± 1.3	6.5 ± 2.0	7.5 ± 0.77	6.8 ± 2.5	13 ± 3.3	12 ± 2.4
AUC,[b] μg·h/mL	0.75 ± 0.52	2.26 ± 1.02	2.56± 0.53	3.66 ± 1.00	4.87 ± 1.41	13.2 ± 2.80	17.3 ± 2.18
CL_T, L/h/kg,	0.29 ± 0.20	0.20 ± 0.10	0.28 ± 0.04	0.29 ± 0.04	0.30 ± 0.08	0.23 ± 0.04	0.25 ± 0.03
$t_{1/2}$, h	11 ± 10	32 ± 20	18 ± 3.6	22 ± 5.3	22 ± 10	52 ± 12	44 ± 7.8
Multiple doses[c]							
C_{max}[a], μg/mL	…	0.32 ± 0.05	0.62 ± 0.09	…	1.17 ± 0.18	…	…
V_{ss}, L/kg	…	8.6 ± 1.98	7.2 ± 0.50	…	9.1 ± 2.91	…	…
AUC,[b] μg·h/mL	…	1.48 ± 0.26	3.07 ± 0.38	…	4.98 ± 0.93	…	…
CL_T, L/h/kg	…	0.20 ± 0.04	0.20 ± 0.02	…	0.24 ± 0.05	…	…
$t_{1/2}$, h	…	49 ± 35	37 ± 12	…	66 ± 23	…	

NOTE. Data are mean ± SD. AUC, area under the concentration–time curve; CL_T, total clearance; C_{max}, maximum concentration; $t_{1/2}$, elimination half-life; V_{ss}, apparent volume of distribution at steady state.

[a] Concentration following a 1-h infusion.

[b] AUC from time zero to infinity for single dose studies and 12-h AUC at steady state for multiple-dose studies.

[c] Multiple doses were given every 12 h.

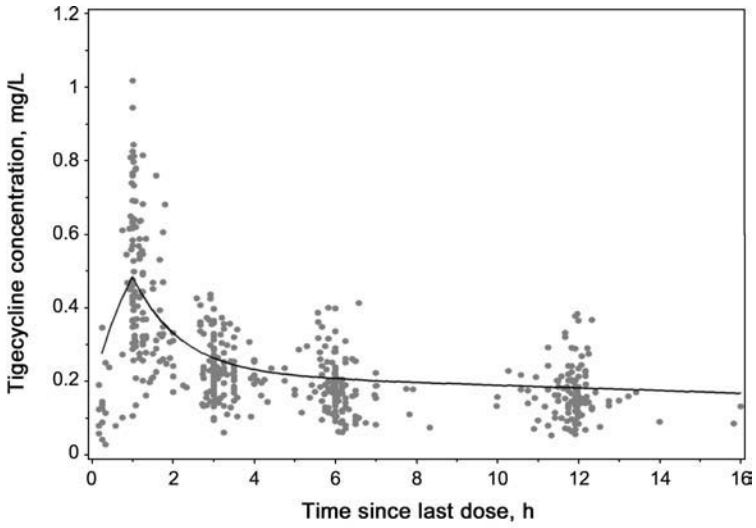

Figure 3. Population mean predicted steady-state concentration-time profile *(line)* for tigecycline, overlaid on observed data *(circles)* for patients in phase 2 and phase 3 clinical trials treated with a 100-mg loading dose and 50 mg every 12 h infused over 1 h.

weight, with AUC decreasing with increasing weight. Similar to the assessment of C_{max}, normalizing the parameter by body weight did not completely explain this association, and the AUC was explored by comparing 26 subjects in similar weight ranges and using only the 100-mg dose group on day 1. Within similar weight ranges, the median AUC values were 5.94 and 4.78 μg·h/mL for male and female subjects, respectively. Significant differences in AUC values across all race and age groups were not detected.

The median V_{ss} for tigecycline ranged from 2.95 to 12.7 L/kg across dose levels and treatment days. Significant differences in V_{ss} based on age, sex, or race were not detected. The $t_{1/2}$ for the 50-, 75-, 100-, 200-, and 300-mg dose arms on day 1 were ~17, 20, 23, 49, and 44 h, respectively ($P < .001$). There were no significant differences in $t_{1/2}$ on the basis of age, sex, race, or renal function.

Evaluation of CL_T revealed a strong relationship between body weight and clearance of tigecycline, with values ranging from 0.20 to 0.31 L/h/kg in the total population. A wide interindividual variability in CL_T was also noted within the population of healthy subjects. Clearance of tigecycline appeared to increase with decreasing calculated creatinine clearance. Differences in clearance across the dose range tested were not detected, indicative of linear kinetics. CL_T was not significantly affected by age. Evaluation of the potential effect of race on the CL_T of tigecycline, however, revealed a statistically significant difference between healthy young white subjects (median CL_T, 0.240 L/h/kg) versus black subjects (median CL_T, 0.325 L/h/kg), with a 35% increase in median CL_T for black subjects ($P = .0018$). However, with only 11 black subjects, conclusions regarding racial differences in the clearance of tigecycline will require further evaluation.

From a meta-analysis, the pharmacokinetics of tigecycline were not affected by severe renal impairment or ESRD, including those subjects receiving hemodialysis. However, slight trends for differences in pharmacokinetic parameters for age, race, and sex were identified. Elderly subjects had significantly higher C_{max} values than did younger subjects. Female subjects tended to have higher CL_T, lower V_{ss}, shorter $t_{1/2}$, and higher C_{max} values than did male subjects, and black subjects tended to have higher CL_T, lower V_{ss}, and shorter $t_{1/2}$ than did nonblack subjects. However, because of the small sample size of the various subpopulations analyzed, the clinical significance of these differences will require further evaluation in subsequent population pharmacokinetic analyses.

Finally, the preliminary pharmacokinetic profile of tigecycline in a population of patients has been established in a noncompartmental analysis of data from 15 patients with complicated skin and skin-structure infections from a phase 3 randomized trial [20]. After a 100-mg intravenous loading dose of tigecycline and 50 mg infused over 60 min every 12 h for up to 14 days, the mean ($\pm$SD) C_{max} and 12-h steady-state AUC were 0.63 $\pm$ 0.28 μg/mL and 3.04 $\pm$ 0.82 μg·h/mL, respectively. These data supported the previous conclusion that steady-state conditions were reached before administration of the seventh dose.

CONCLUSIONS

Tigecycline, a first-in-class glycylcycline antimicrobial agent, has an expanded spectrum of activity against gram-positive, gram-negative, aerobic, anaerobic, and atypical bacteria, including strains that are multidrug resistant. It is active against methicillin-resistant *S. aureus,* penicillin-resistant *S. pneumoniae,* vanco-

mycin-resistant *Enterococcus* species, and expanded-spectrum β-lactamase–producing *E. coli* and *K. pneumoniae*. Tigecycline is available as an intravenous formulation and has displayed a favorable pharmacokinetic profile, with extensive tissue distribution and a long $t_{1/2}$. Additional data regarding tissue concentrations in humans, such as concentrations in epithelial lining fluid, will help to elucidate the complete profile for tigecycline. Preliminary analyses to identify the pharmacokinetic/pharmacodynamic index associated with efficacy point to the ratio of AUC to MIC as the index most likely to correlate with success. Analysis of clinical data, however, is needed to confirm the pharmacodynamic index and its magnitude required for clinical and microbiological efficacy. Tigecycline has been extensively studied in the treatment of complicated skin and skin-structure infections and complicated intra-abdominal infections and should prove to be a promising, and much needed, addition to our antimicrobial armamentarium.

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