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(57) Abrégé/Abstract:
This disclosure relates to the treatment of intrapulmonary bacterial infections, including treatment of nosocomial pneumonia lung infections with pharmaceutical compositions containing the cephalosporin ceftolozane.

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(54) **Title**: METHODS FOR TREATING INTRAPULMONARY INFECTIONS

(57) **Abstract**: This disclosure relates to the treatment of intrapulmonary bacterial infections, including treatment of nosocomial pneumonia lung infections with pharmaceutical compositions containing the cephalosporin ceftolozane.

METHODS FOR TREATING INTRAPULMONARY INFECTIONS

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application No. 61/532,914, filed September 9, 2011, titled "Methods for Treating Intrapulmonary Infections," and U.S. Provisional Application No. 61/657,386, filed June 8, 2012, titled "Methods for Treating Intrapulmonary Infections." The contents of any patents, patent applications, and references cited throughout this specification are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

This disclosure relates to the treatment of intrapulmonary bacterial infections, including the treatment of nosocomial pneumonia infections, with a cephalosporin.

BACKGROUND

The cephalosporin (6R,7R)-3-[5-Amino-4-[3-(2-aminoethyl)ureido]-1-methyl-1H-pyrazol-2-ium-2-ylmethyl]-7-[2-(5-amino-1,2,4-thiadiazol-3-yl)-2-[(Z)-1-carboxy-1-methylethoxyimino]acetamido]-3-cephem-4-carboxylic acid (also referred to as "CXA-101" and previously designated FR264205) is an antibacterial agent. CXA-101 can be provided as the compound shown in Figure 1. The antibacterial activity of CXA-101 is believed to result from its interaction with penicillin binding proteins (PBPs) to inhibit the biosynthesis of the bacterial cell wall which acts to stop bacterial replication. CXA-101 can be combined (e.g., mixed) with a β-lactamase inhibitor ("BLI"), such as tazobactam. Tazobactam is a BLI against Class A and some Class C β-lactamases, with well established *in vitro* and *in vivo* efficacy in combination with active β-lactam antibiotics. The combination of CXA-101 and tazobactam in a 2:1 weight ratio is an antibiotic pharmaceutical composition ("CXA-201") for parenteral administration. CXA-201 displays potent antibacterial activity *in vitro* against common Gram-negative and selected Gram-positive organisms. CXA-201 is a broad-spectrum antibacterial with *in vitro* activity against Enterobacteriaceae including strains expressing extended spectrum β-lactamases-resistant (MIC_{90} = 1 μg/mL), as well as *Pseudomonas aeruginosa* (*P. aeruginosa*) including multi-drug resistant strains (MIC_{90}= 2 μg/mL). CXA-201 is a combination antibacterial with activity against many Gram-negative

pathogens known to cause intrapulmonary infections, including nosocomial pneumonia caused by *P. aeruginosa*.

Intrapulmonary infections, such as nosocomial pneumonia, remain a major cause of morbidity and mortality, especially infections caused by drug resistant pathogens such as *P. aeruginosa*. One challenge in treating intrapulmonary infections with systemic administration of an antibiotic is determining the antibiotic dose that will provide a therapeutically safe and effective concentration of the antibiotic at the site of an infection on the mucosal side of the bronchi in the lung (i.e., in the bronchial secretions). Many antibiotics diffuse poorly from the bloodstream across the bronchi [e.g., Pennington, J. E., "Penetration of antibiotics into respiratory secretions," *Rev Infect Dis* 3(1):67-73 (1981)], which can result in the administration of higher doses of antibiotic than would be prescribed for a truly systemic infection. Furthermore, the purulent sputum that characterizes infected patients tends to compromise the potency of many antibiotics (*See e.g.,* Levy, J., et al., "Bioactivity of gentamicin in purulent sputum from patients with cystic fibrosis or bronchiectasis: comparison with activity in serum," J Infect Dis 148(6):1069-76 (1983)). In some cases, the result is the prescription of large amounts of a systemically administered antibiotic to treat an intrapulmonary infection.

The efficacy of an antibiotic depends in part on the concentration of the drug at the site of action. Efficacy of antimicrobial therapy requires adequate antibiotic concentrations at the site of bacterial infection, and some authorities believe that epithelial lining fluid (ELF) concentrations are a reasonable surrogate for predicting effective concentrations for treating intrapulmonary infections such as pneumonia. For many antibiotics, clinical data correlating ELF concentrations to clinical outcome is unavailable and the clinical significance of differences in pulmonary penetration of antibiotics is unknown or poorly characterized. Few studies have quantified the penetration of β-lactam agents into the lung, as measured by the ratio of area under the concentration-time curve (AUC) in ELF to AUC in plasma (AUC(ELF)/AUC(plasma) ratio). For some published studies, the concentration of antibiotics measured in the ELF of the lung has varied widely. For example, the reported penetration ratio of telavancin in healthy human volunteers ranges widely between 0.43 and 1.24 (Lodise, Gottfreid, Drusano, 2008 Antimicrobial Agents and Chemotherapy). Thus, predicting the penetration of a drug into the ELF *a priori*, based on the structure, molecular weight,

size and solubility is difficult due to the limited data available on the effect of physicochemical properties on the lung penetration of drugs.

Accordingly, the efficacy of a particular drug in treating intrapulmonary infections, in particular nosocomial pneumonia, cannot be predicted solely on the basis of data, such as *in vitro* data relating to the activity of that drug against a particular bacterium, which does not give any indication as whether the drug will accumulate at a therapeutically safe and effective concentration at the site of an infection on the mucosal side of the bronchi in the lung (i.e., in the bronchial secretions). For instance, tigicycline, a glycylcycline antimicrobial, has *in vitro* activity against many species of Gram-positive and Gram-negative bacteria, including *P. aeruginosa*, and it has been approved by the FDA for the treatment of complicated skin and skin structure infections, complicated intra-abdominal infections, and community acquired pneumonia. However, tigicycline is not approved for the treatment of nosocomial pneumonia, in view of an increased mortality risk associated with the use of tigicycline compared to other drugs in patients treated for nosocomial pneumonia.

SUMMARY

The present invention provides methods for treating intrapulmonary infections, including nosocomial pneumonia, with systemic administration of a pharmaceutical composition comprising ceftolozane. The invention is based in part on results from a human clinical study designed to assess the ELF penetration of CXA-201 in comparison to piperacillin/tazobactam, indicated for the treatment of nosocomial pneumonia. The study described herein quantified the penetration of CXA-201 into the lung, as measured by the ratio of area under the concentration-time curve (AUC) in epithelial lining fluid (ELF) to AUC in plasma (AUC(ELF)/AUC(plasma) ratio). The results of the study indicate that CXA-201 penetrated into the ELF of human patients, with a ceftolozane ELF/plasma AUC ratio of 0.48. The measured ELF concentrations of ceftolozane exceeded 8 μg/mL for 60% of the 8-hour dosing interval, a concentration that is predicted to inhibit 99% of *Pseudomonas aeruginosa* based on current surveillance data.

The study showed that CXA-201 penetrated well into the ELF of healthy volunteers compared to piperacillin/tazobactam, an agent widely used for treatment of lower respiratory infections. The intrapulmonary pharmacokinetics measured in the study supports the use of CXA-201 as a parenteral (e.g., intravenous) antibiotic for

treatment of intrapulmonary infections, such as nosocomial pneumonia or other lower respiratory tract infections.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is the chemical structure of a salt of ceftolozane hydrogen sulfate salt .

Figure 2A is a graph showing the ELF Concentration vs. Time Profile for ceftolozane hydrogen sulfate salt (Median and Range) for CXA-201.

Figure 2B is a graph showing the ELF Concentration vs. Time Profile for Tazobactam (Median and Range) for CXA-201.

Figure 3A is a graph showing the (Comparative) ELF Concentration vs. Time Profile for Piperacillin (Median and Range) for a piperacillin/tazobactam comparator (ZOSYN®).

Figure 3B is a graph showing the (Comparative) ELF Concentration vs. Time Profile for Tazobactam (Median and Range) for a piperacillin/tazobactam comparator (ZOSYN®).

Figures 4A and 4B are synthetic schemes for preparing ceftolozane hydrogen sulfate salt .

DETAILED DESCRIPTION

The present disclosure relates to the treatment of intrapulmonary infections, including nosocomial pneumonia, with systemic administration of a pharmaceutical composition comprising ceftolozane, including the parenteral administration of a therapeutically effective amount of a pharmaceutical composition comprising ceftolozane and tazobactam. As used herein, the term "ceftolozane" means CXA-101 in a free-base or salt form, preferably a hydrogen sulfate form (illustrated in figure 1). In one embodiment, ceftolozane is CXA-101 in its free-base form. In another embodiment, ceftolozane is CXA-101 in its salt form, preferably a hydrogen sulfate form.

In a preferred embodiment, ceftolozane (in free base or salt form, preferably hydrogen sulfate form) and tazobactam are in a 2:1 (ceftolozane:tazobactam) weight ratio. In a particular embodiment, provided herein are methods of treating intrapulmonary infections, including nosocomial pneumonia, with systemic administration of a pharmaceutical composition comprising ceftolozane hydrogen sulfate and tazobactam in a 2:1 weight ratio. The combination of ceftolozane hydrogen

sulfate and tazobactam in a 2:1 weight ratio is referred to herein and in the examples as "CXA-201."

In one aspect, the invention provides a method of treating an intrapulmonary infection comprising administering a therapeutically effective amount of a pharmaceutical composition comprising ceftolozane. The method may comprise administering a pharmaceutical composition comprising ceftolozane in combination with tazobactam.

In another aspect, the invention provides a method of treating an intrapulmonary infection comprising the step of intravenously administering about every 8 hours to a subject in need thereof a pharmaceutical composition comprising 3.0 g of ceftolozane. The method may comprise administering a pharmaceutical composition comprising ceftolozane in combination with tazobactam. In one embodiment, the method comprises administering CXA-201 and the infection comprises Gram-negative bacteria. In another aspect, the invention provides a method of treating an intrapulmonary infection comprising the step of intravenously administering every 8 hours to a subject in need thereof a pharmaceutical composition comprising 3.0 g of ceftolozane.

In another aspect, the invention provides a method of providing tazobactam or ceftolozane in the epithelial lining fluid of a subject in an amount effective to treat an intrapulmonary infection, comprising the step of intravenously administering to the subject a pharmaceutical composition comprising ceftolozane. The method may comprise administering a pharmaceutical composition further comprising tazobactam, optionally wherein the pharmaceutical composition is CXA-201. The method may comprise administering about 1.5 g of ceftolozane and tazobactam in total every 8 hours. In one embodiment, the amount of the ceftolozane in the ELF of the subject effective to treat an intrapulmonary infection is at least about 8 μg/ml. The ELF concentration of ceftolozane in the ELF may reach at least about 8 μg/ml after administration of the pharmaceutical composition. The subject is typically a human having, or believed to be at risk of having, nosocomial pneumonia. The subject (or patient) may, in some embodiments, have ventilator acquired pneumonia or hospital acquired pneumonia.

In another aspect, the invention provides the use of ceftolozane in the manufacture of a medicament for the treatment of an intrapulmonary infection comprising administering a therapeutically effective amount of a pharmaceutical

composition comprising the ceftolozane. The use may comprise administering the pharmaceutical composition comprising ceftolozane, in combination with tazobactam.

In another aspect, the invention provides the use of ceftolozane in the manufacture of a medicament for the treatment of an intrapulmonary infection comprising intravenously administering a pharmaceutical composition comprising 3.0 g of the ceftolozane every 8 hours to a subject in need thereof. The use may comprise administering the pharmaceutical composition comprising ceftolozane in combination with tazobactam. In one embodiment, the use comprises administering ceftolozane and tazobactam and the infection comprises Gram-negative bacteria.

In another aspect, the invention provides the use of ceftolozane in the manufacture of a medicament for the treatment of an intrapulmonary infection comprising intravenously administering a pharmaceutical composition comprising the ceftolozane, wherein tazobactam or ceftolozane is provided in the epithelial lining fluid of a subject in an amount effective to treat the intrapulmonary infection. The use may comprise administering a pharmaceutical composition further comprising tazobactam, optionally wherein the pharmaceutical composition is CXA-201. The use may comprise administering about 1.5 g of ceftolozane and tazobactam every 8 hours. In one embodiment, the amount of the ceftolozane in the ELF of the subject effective to treat an intrapulmonary infection is at least about 8 μg/ml. The ELF concentration of ceftolozane in the ELF may reach at least about 8 μg/ml after administration of the pharmaceutical composition. The subject is typically a human having, or believed to be at risk of having, nosocomial pneumonia. The subject (or patient) may, in some embodiments, have ventilator acquired pneumonia or hospital acquired pneumonia. In the methods and uses of the invention, the pharmaceutical composition may be administered parenterally. The pharmaceutical composition may be administered intravenously. In some embodiments, the pharmaceutical composition is intravenously administered about once every 8 hours as an infusion. The pharmaceutical composition may be intravenously administered as a 60-minute infusion.

In the methods and uses of the invention, the intrapulmonary infection may be an infection in the lung. The intrapulmonary infection may be pneumonia. In a preferred embodiment, the intrapulmonary infection is nosocomial pneumonia. The intrapulmonary infection may comprise *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof. Typically, the intrapulmonary infection comprises

Pseudomonas aeruginosa. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for CXA-201 of ≤ 8μg/ml. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane of ≤ 8μg/ml.

In another aspect, the invention provides ceftolozane, for use in a method of treating an intrapulmonary infection. In one embodiment, the ceftolozane is parenterally administered. Typically, the ceftolozane is intravenously administered. In some embodiments, the ceftolozane is administered about once every 8 hours as an infusion. In some embodiments, the ceftolozane is intravenously administered as a 60-minute infusion.

In one embodiment, the ceftolozane is for use in a method of treating an intrapulmonary infection wherein the intrapulmonary infection comprises an infection in the lung. The intrapulmonary infection may be pneumonia. In a preferred embodiment, the ceftolozane is for use in a method of treating nosocomial pneumonia. The intrapulmonary infection may comprise *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof. Typically, the intrapulmonary infection comprises *Pseudomonas aeruginosa*. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of ≤ 8μg/ml. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane of ≤ 8μg/ml.

The invention also provides ceftolozane, for use in a method of treating an intrapulmonary infection, comprising administration of ceftolozane in combination with tazobactam. In one embodiment, the ceftolozane and/or tazobactam is parenterally administered. Typically, the ceftolozane and/or tazobactam is intravenously administered. In some embodiments, the ceftolozane and/or tazobactam is administered about once every 8 hours as an infusion. In some embodiments, the ceftolozane and/or tazobactam is intravenously administered as a 60-minute infusion. In one embodiment, both the ceftolozane and tazobactam are parenterally administered. In another embodiment, both the ceftolozane and tazobactam are intravenously administered. In some embodiments, both the ceftolozane and tazobactam are administered about once every 8 hours as an infusion. In some embodiments, both the ceftolozane and tazobactam are intravenously administered as a 60-minute infusion.In one embodiment, the ceftolozane is for use in a method of treating an intrapulmonary infection wherein

the intrapulmonary infection comprises an infection in the lung. The intrapulmonary infection may be pneumonia. In a preferred embodiment, the ceftolozane is for use in a method of treating nosocomial pneumonia. The intrapulmonary infection may comprise *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof. Typically, the intrapulmonary infection comprises *Pseudomonas aeruginosa*. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of $\leq 8\mu g/ml$. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane of $\leq 8\mu g/ml$.

In another aspect, the invention provides tazobactam, for use in a method of treating an intrapulmonary infection, comprising administration of tazobactam in combination with ceftolozane. In one embodiment, the tazobactam and/or ceftolozane is parenterally administered. Typically, the tazobactam and/or ceftolozane is intravenously administered. In some embodiments, the tazobactam and/or ceftolozane is administered about once every 8 hours as an infusion. In some embodiments, the tazobactam and/or ceftolozane is intravenously administered as a 60-minute infusion. In one embodiment, both the tazobactam and ceftolozane are parenterally administered. In another embodiment, both the tazobactam and ceftolozane are intravenously administered. In another embodiment, both the tazobactam and ceftolozane are administered about once every 8 hours as an infusion. In another embodiments, both the tazobactam and ceftolozane are intravenously administered as a 60-minute infusion.

In one embodiment, the tazobactam is for use in a method of treating an intrapulmonary infection wherein the intrapulmonary infection comprises an infection in the lung. The intrapulmonary infection may be pneumonia. In a preferred embodiment, the tazobactam is for use in a method of treating nosocomial pneumonia. The intrapulmonary infection may comprise *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof. Typically, the intrapulmonary infection comprises *Pseudomonas aeruginosa*. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of $\leq 8\mu g/ml$. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane of $\leq 8\mu g/ml$.

In another aspect, the invention provides ceftolozane and tazobactam, as a combined preparation for simultaneous, separate or sequential use in a method of treating an intrapulmonary infection. In one embodiment, the ceftolozane and

tazobactam are parenterally administered. Typically, the ceftolozane and tazobactam are intravenously administered. In some embodiments, the ceftolozane and tazobactam are administered about once every 8 hours as an infusion. In some embodiments, the ceftolozane and tazobactam, are intravenously administered as a 60-minute infusion.

In one embodiment, the ceftolozane and tazobactam are for use in a method of treating an intrapulmonary infection wherein the intrapulmonary infection comprises an infection in the lung. The intrapulmonary infection may be pneumonia. In a preferred embodiment, the ceftolozane and tazobactam are for use in a method of treating nosocomial pneumonia. The intrapulmonary infection may comprise *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof. Typically, the intrapulmonary infection comprises *Pseudomonas aeruginosa*. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of $\leq 8\mu g/ml$. The intrapulmonary infection may comprise a pathogen with minimum inhibitory concentration for ceftolozane of $\leq 8\mu g/ml$.

In another aspect, the invention provides ceftolozane for use in a method of providing tazobactam or ceftolozane in the epithelial lining fluid of a subject in an amount effective to treat an intrapulmonary infection, comprising the step of intravenously administering ceftolozane. In some embodiments, ceftolozane is administered in combination with tazobactam. Preferably, CXA-201 is administered. In preferred embodiments, about 1.5 g of ceftolozane and tazobactam is administered every 8 hours. In one embodiment, the amount of the ceftolozane in the ELF of the subject effective to treat an intrapulmonary infection is at least about 8 μg/ml. The ELF concentration of ceftolozane in the ELF may reach at least about 8 μg/ml after administration of the ceftolozane. The subject is typically a human having, or believed to be at risk of having, nosocomial pneumonia. The subject (or patient) may, in some embodiments, have ventilator acquired pneumonia or hospital acquired pneumonia.

The safe and effective treatment of intrapulmonary infection with CXA-201 includes administration of an amount of the CXA-201 selected to provide a therapeutically effective dose of the CXA-201 antibiotic in the epithelial lining fluid (ELF). The penetration of CXA-201 into the ELF compared to a piperacillin/tazobactam comparator was assessed in a Phase 1 clinical study in healthy adult volunteers. The piperacillin/tazobactam comparator contained piperacillin/tazobactam in an 8:1 weight ratio with a total of 2.79 mEq of sodium per gram of piperacillin, FDA approved under

the tradename ZOSYN® ("Zosyn"). The study results evaluate the penetration of intravenously administered CXA-201 into healthy human lungs, as measured by the ratio of area under the concentration-time curve (AUC) in epithelial lining fluid (ELF) to AUC in plasma (AUC(ELF)/AUC(plasma) ratio).

In the study, a 4.5 g amount of piperacillin/tazobactam incorporates the same dose of tazobactam (0.5 g) as 1.5 g of CXA-201. A multiple-dose regimen was used in this study to ensure that the concentrations of the analytes reached steady-state in both plasma and ELF prior to assessment. Healthy volunteers were chosen to standardize the subject population and minimize the variability associated with using actively ill patients. The objectives of the study included: (1) determination and comparison of the ELF to plasma concentration ratios of multiple-doses of intravenous CXA-201 compared to piperacillin/tazobactam in healthy adult volunteers, and (2) assessment of the safety and tolerability of multiple-doses of intravenous CXA-201 in healthy adult volunteers.

The study was a Phase 1 prospective, randomized (1:1), comparator controlled, open-label study of 50 healthy adult volunteers. Each healthy volunteer received 3 doses of either CXA-201(1.5 grams every 8 hours as a 60-minute infusion) or piperacillin/tazobactam (4.5 grams every 6 hours as a 30-minute infusion). Subjects received 3 doses of a study drug, underwent serial blood draws at planned plasma sampling timepoints, and underwent a single bronchoalveolar lavage (BAL) procedure at one of the scheduled timepoints (Table 1).

Table 1: Plasma Sampling and BAL Timepoints

Plasma Sampling Timepoints	**BAL Timepoints**
Intensive plasma sampling from all 25 subjects for one dosing interval	5 subjects per timepoint per treatment group; in hours from start of the third infusion
CXA-201	
0 (pre-PK dose trough) ,1,2,4,6,8 hours post start of infusion of the third dose of CXA 201	1,2,4,6,8 hours post start of infusion of the third dose of CXA 201
Piperacillin/tazobactam	
0 (pre-PK dose trough) ,0.5,1,2,4,6 hours post start of infusion of the third dose of piperacillin/tazobactam	0.5,1,2,4,6 hours post start of infusion of the third dose of piperacillin/tazobactam

A total of 51 subjects were enrolled; 25 in the CXA-201 group and 26 in the piperacillin/tazobactam group. Key Inclusion Criteria for the study were: (1) healthy adult male or non-pregnant females between 18 and 50 years, inclusive; (2) body mass index between 18.5 and 30; and (3) forced Expiratory Volume in 1 second (FEV1) ≥ 80%. Key Exclusion Criteria for the study were: (1) pregnancy or lactation; (2) clinically significant systemic disease or the existence of any surgical or medical condition that may have interfered with the distribution, metabolism, or excretion of CXA-201; (3) history of asthma or any restrictive or obstructive lung disease; (4) history of smoking or abuse of narcotics or alcohol; (5) positive test for human immunodeficiency virus, Hepatitis B surface antigen, or Hepatitis C antibodies; (6) any condition or situation where bronchoscopy was not advisable; and (7) impairment of renal function (CrCl < 90 mL/min).

Determination of the ELF to plasma concentration ratios of multiple-doses of intravenous CXA-201 compared to piperacillin/tazobactam in healthy adult volunteers.

Plasma and BAL datapoints were used to construct one concentration-time profile in the ELF using the mean concentrations at each time point. After dosing, a single ELF sample was obtained by bronchoalveolar lavage (BAL) from each healthy volunteer at one of 5 scheduled time points (5 subjects/time point/treatment group). The ELF to plasma concentrations of multiple-doses was determined. Serial plasma samples were collected pre- and post-treatment over a 6-hour (piperacillin/tazobactam) or 8-hour (CXA-201) time period. Urea levels in the plasma and BAL were used to calculate the ELF drug concentrations (see Table 1). Pharmacokinetic parameters for ELF were calculated by non-compartmental analysis using the mean concentrations at each time point. The intrapulmonary penetration of CXA-201 into the ELF was determined by dividing the ELF AUC_0-t by mean plasma AUC_0-t.

The concentration of CXA-201 and piperacillin/tazobactam in ELF were estimated from the concentration of drug in BAL fluid, the volume of BAL fluid collected, and the ratio of urea concentration in BAL fluid to that in plasma. Calculation of ELF volume was determined by the urea dilution method, using urea as an endogenous marker of ELF recovered by BAL. Concentration of CXA-201 and piperacillin/tazobactam in ELF was estimated from the concentration of drug in BAL

fluid, the volume of BAL fluid collected, and the ratio of urea concentration in BAL fluid to that in plasma. The following formulas represent these calculations:

$$\text{CXA-201 (CXA/T)} = [\text{CXA/T}]_{BAL} \times V_{BAL}/V_{ELF}$$

$[CXA/T]_{BAL}$ is the concentration of CXA-201 in BAL fluid; V_{BAL} is the volume of aspirated BAL fluid (total); V_{ELF} is $V_{BAL} \times [urea]_{BAL}/[urea]_{plasma}$, where $[urea]_{BAL}$ is the concentration of urea in the BAL fluid (supernatant) and $[urea]_{plasma}$ is the concentration of urea in the plasma specimens.

$$\text{Piperacillin/tazobactam} = [\text{PIP/T}]_{BAL} \times V_{BAL}/V_{ELF}$$

[PIP/T]BAL is the concentration of piperacillin/tazobactam in BAL fluid; V_{BAL} is the volume of aspirated BAL fluid (total); V_{ELF} is $V_{BAL} \times [urea]_{BAL}/[urea]_{plasma}$, where $[urea]_{BAL}$ is the concentration of urea in the BAL fluid (supernatant) and $[urea]_{plasma}$ is the concentration of urea in the plasma specimens.

No oral antibiotic therapy was permitted. Safety was monitored through the review of vital signs, laboratory and physical examinations and the occurrence of adverse events (AEs). Subjects who received three doses of study medication and had both BAL and plasma samples collected were included in the pharmacokinetic (PK) analysis population. All randomized subjects who received any dose (including partial doses) of study medication were included in the safety analysis population.

The results of the study (Table 2) indicate that CXA-201 penetrated well into ELF. The ceftolozane component of CXA-201 ELF/plasma AUC ratio was 0.48, compared to 0.26 for the piperacillin component of piperacillin/tazobactam. The ELF concentrations of ceftolozane exceeded 8 μg/mL for 60% of the 8-hour dosing interval. The plasma concentrations for ceftolozane were consistent with those seen previously at this dose.

The ELF concentration vs. time profiles for ceftolozane and tazobactam components of CXA-201 are shown in Figures 2A and 2B, respectively. Comparative data showing the ELF concentration vs. time profiles for piperacillin and tazobactam components of the comparator drug are shown in Figures 3A and 3B, respectively. The ELF to plasma penetration ratios are shown in Table 2.

The PK parameters were determined by non-compartmental PK analysis. PHOENIX® WinNonlin v 6.1 (PHARSIGHT®, Mountain View, California) was used for the derivation of all PK individual measures for each subject. The PK parameters for ELF were calculated by taking the mean concentrations of the 5 subjects at each time

point and constructing a single profile over the duration of sampling. In the event that the urea concentrations determined in plasma or ELF were below quantifiable limits, thereby providing only an estimate of concentration, those values were not used in the calculation of mean concentration at that time point. The ceftolozane, piperacillin, and tazobactam PK parameters that were computed in plasma and ELF were:

- C_{max} (μg/mL): Maximum plasma and ELF concentration over the entire sampling phase directly obtained from the experimental plasma concentration time data, without interpolation.
- T_{max} (hr): Sampling time at which C_{max} occurred, obtained directly from the experimental plasma and ELF concentration time data, without interpolation.
- C_{last} (μg/mL): Plasma or ELF concentration when last quantifiable concentration was observed, relative to the end of infusion.
- T_{last} (hr): Time when the last quantifiable concentration was observed.
- AUC_{0-t} (μg*hr/mL): An area under the concentration time curve from the time of the dose to the end of the dosing interval.
- Percent penetration into ELF: Calculated as the ratio of AUC_{0-tELF} and mean $AUC_{0-tPlasma}$.

Table 2: Summary of ELF to Plasma Penetration Ratios

Analyte	Mean Plasma $AUC_{0-\tau}$ (μg*hr/mL)	ELF $AUC_{0-\tau}$ (μg*hr/mL)	ELF Penetration Ratio
ceftolozane (in CXA-201)	158.5	75.1	0.48
Tazobactam (in CXA-201)	19.3	8.5	0.44
Piperacillin (in piperacillin/tazobactam)	357.3	94.5	0.26
Tazobactam (in piperacillin/tazobactam)	46.1	24.7	0.54

The ELF/plasma AUC ratio for the ceftolozane component of CXA-201 was 0.48, compared to 0.26 for the piperacillin component of the comparator drug (piperacillin/tazobactam). The ELF/plasma AUC ratio for tazobactam was 0.44 and 0.54 when given as part of CXA-201 and piperacillin/tazobactam, respectively. The ELF concentrations of ceftolozane exceeded 8 μg/mL for 60% of the 8-hour dosing interval. The plasma and ELF concentrations of tazobactam when given as

piperacillin/tazobactam was approximately 2-fold higher than when an equivalent dose was given as CXA-201.

The results show that ceftolozane and tazobactam (i.e., administered as CXA-201) penetrated well into the ELF of healthy volunteers compared to piperacillin/tazobactam, an agent widely used for treatment of lower respiratory infections. CXA-201's intrapulmonary pharmacokinetics support use of CXA-201 as a parenteral (e.g., intravenous) antibiotic for treatment of lower respiratory tract infections, including infections caused by pathogens with minimum inhibitory concentrations of ≤ 8μg/ml. The concentrations of ceftolozane in ELF exceeded 8 μg/mL, a concentration that inhibits 99% of *P. aeruginosa*, for approximately 60% of the 8–hour dosing interval for the CXA-201 regimen of 1.5 grams every eight hours as a 60 minute infusion.

Assessment of the safety and tolerability of multiple-doses of intravenous CXA-201 in healthy adult volunteers.

Among the subjects, 50 of the 51 (98%) subjects received all 3 doses of study medication and completed the BAL procedure. One subject prematurely discontinued piperacillin/tazobactam and terminated their participation in the study due to an AE of hypersensitivity that occurred during administration of the first dose. Demographics and baseline characteristics are summarized in Table 3, the two treatment arms were well balanced.

Table 3: Demographics and Baseline Characteristics (Safety Population)

	CXA-201 1.5 grams (N=25)	Piperacillin/ tazobactam 4.5 grams (N=26)
Sex, n (%)		
Female	11 (44.0)	11 (42.3)
Male	14 (56.0)	15 (57.7)
Age, years		
Mean (SD)	32.6 (7.8)	34.2 (8.5)
Minimum, Maximum	21, 47	22, 49
Race, n (%)		
White	20 (80.0)	21 (80.8)
Black or African American	2 (8.0)	2 (7.7)
Asian	1 (4.0)	0 (0.0)

	CXA-201 1.5 grams (N=25)	Piperacillin/ tazobactam 4.5 grams (N=26)
American Indian or Alaska Native	0 (0.0)	1 (3.8)
Native Hawaiian or Pacific Islander	1 (4.0)	0 (0.0)
Other	1 (4.0)	2 (7.7)
BMI, kg/m^2		
Mean (SD)	26.21 (2.6)	23.23 (2.4)
Minimum, Maximum	22.3, 30.0	20.6, 29.9

During the study, treatment-emergent AEs (TEAEs) occurred in 20.0% (5/25) of subjects receiving CXA-201 and 23.1% (6/26) of subjects receiving piperacillin/tazobactam. No serious AEs were reported in either treatment group. All AEs were mild in severity. The incidence and pattern of AEs were generally similar in the 2 treatment groups, Table 4.

Table 4: TEAEs by Preferred Term (Safety Population)

Subjects with at least 1 TEAE	*5 (20.0)*	*6 (23.1)*
Diarrhea	1 (4.0)	3 (11.5)
Viral Upper Respiratory Infection	1 (4.0)	0 (0)
Musculoskeletal Chest Pain	1 (4.0)	0 (0)
Somnolence	1 (4.0)	0 (0)
Hematuria	1 (4.0)	0 (0)
Cough	1 (4.0)	0 (0)
Type I Hypersensitivity	0 (0)	1 (3.8)
Alanine Aminotransferase Increased	0 (0)	1 (3.8)
Aspartate Aminotransferase Increased	0 (0)	1 (3.8)
Blood Creatine Phosphokinase Increased	0 (0)	1 (3.8)
Hyperkalemia	0 (0)	1 (3.8)

Eight subjects had TEAEs assessed as related to study drug; two in the CXA-201 group (diarrhea and somnolence in 1 subject each) and six in the piperacillin/tazobactam group (diarrhea in 3 subjects, type I hypersensitivity in 1 subject, blood creatine phosphokinase increased in 1 subject, and alanine aminotransferase increased, aspartate aminotransferase increased, and hyperkalaemia all in the same 1 subject). One piperacillin/tazobactam-treated subject discontinued study drug due to an adverse event, type I hypersensitivity. There were no clinically significant changes in safety laboratory assessments or vital signs.

CXA-201 appeared safe and well tolerated in this group of healthy adult subjects.

Determining appropriate dose

A Monte Carlo simulation was performed based on clinical trial data to predict an effective CXA-201 dose for treating nosocomial pneumonia using PHOENIX® NLME (PHARSIGHT®, Mountain View, CA) software, a tool for data processing and modeling for population PK/PD analysis. A population pharmacokinetic (PK) model was developed using the CXA-201 plasma concentration versus time data from a previously conducted Phase 2 study in patients with complicated intra abdominal infections. Estimates of clearance and volume of distribution along with the associated inter-individual variability were obtained from these analyses. The outputs from the PK population model served as inputs for a clinical trial simulation performed using PHARSIGHT® Trial Simulator (PHARSIGHT®) software, a tool for defining and testing interactive drug models, exploring and communicating study design attributes, and performing statistical and sensitivity analysis through graphical and statistical summaries. Based on the mean ELF penetration data, an ELF/Plasma AUC ratio of 0.48 for ceftolozane (modeled as a numerical range of 0.25-0.65) calculated from the ceftolozane ELF study mentioned above was used to generate a random /Plasma AUC ratio from the range 0.25 – 0.65 for each simulated patient. This range reflects a conservative estimate of the potential distribution in a patient population. Using the results from the PK population model and the ELF/Plasma AUC ratio, the model simulated plasma and ELF concentration of CXA-201 versus time profiles for 1,000 hypothetical clinical trial patients with nosocomial pneumonia. The model evaluated the probability of clinical success of the 3.0 g every 8 hour (q8h) dose of CXA-201 against three key pathogens in nosocomial pneumonia. The MIC distribution for these pathogens was imputed from 2008 United States surveillance data. Clinical success was defined as the achievement of an ELF or plasma concentration of ceftolozane higher than the MIC(s) of the lower respiratory pathogen(s) for a given patient. *In vivo* models have demonstrated that, as for typical cephlaosporins, the relavent PK/PD driver for CXA-201 is the percentage of time above MIC during the dosing interval. The target is to achieve concentrations that exceed the MIC of the pathogen for 45-50% of the time between each q8H dose. Thus, a threshold of 50% time above the minimum inhibitory concentration [T>MIC] on Day 7 of treatment was used. Plasma and ELF concentrations

were estimated at 15 time-points post-administration on Day 7 when dosed every 8 hours. The results of these simulations are shown in Table 5.

Table 5: Probability of Target Attainment versus Key Pathogens in Nosocomial Pneumonia Using the Simulated 3.0 g versus the 1.5 g Dose of Ceftolozane/tazobactam

Pathogen	Dosing Regimen	50% T>MIC in Plasma	50% T>MIC in ELF
P. aeruginosa	1.5 g q8h	98.2	94.6
	3.0 g q8h	99.4	98.5
E. coli	1.5 g q8h	96.3	94.2
	3.0 g q8h	98.8	95.5
K. pneumoniae	1.5 g q8h	90.2	87.3
	3.0 g q8h	92.6	89.3

Abbreviation: T > MIC = Time above minimum inhibitory concentration.

These simulations demonstrate that the 3.0 g dose of CXA-201 administered every 8 hours is expected to provide adequate concentrations for treatment of the vast majority of lower respiratory infections caused by these pathogens.

Following these simulations, the safety and tolerability of a 10 day course of CXA-201 3.0 g IV q8h was evaluated in healthy human volunteers. Subjects were randomized to receive either 3.0 g (2.0/1.0 g) CXA-201 (n=8), 1.5 g (1.0/0.5 g) CXA-201 (n=4), or placebo (n=4). The data showed that CXA-201 was generally safe and well tolerated in this study. There were no serious adverse events or deaths reported in this study.

In conclusion, given the pharmacokinetic simulations conducted, the favorable data from the intrapulmonary PK study and demonstrated safety and tolerability of the higher dose of CXA-201 in the Phase 1 study mentioned above, the data provide justification for the use of 3.0 g CXA-201 IV q8h for the treatment of patients with nosocomial pneumonia caused by Gram-negative pathogens.

Preparing CXA-201

CXA-201 can be prepared by combining ceftolozane and tazobactam in a 2:1 weight ratio. CXA-201 can be obtained using methods described in US patent 7,129,232 and Toda *et al*., "Synthesis and SAR of novel parenteral anti-pseudomonal cephalosporins: Discovery of FR264205," *Bioorganic & Medicinal Chemistry Letters*, 18, 4849-4852 (2008), incorporated herein by reference in its entirety.

According to the method disclosed in Toda *et al*., "Synthesis and SAR of novel parenteral anti-pseudomonal cephalosporins: Discovery of FR264205," *Bioorganic & Medicinal Chemistry Letters*, 18, 4849-4852 (2008), ceftolozane can be obtained by the synthetic schemes of Figures 4A and 4B. Referring to Figures 4A and 4B, synthesis of ceftolozane can be performed via activation of the thiadiazolyl-oximinoacetic acid derivative (I) with methanesulfonyl chloride and K_2CO_3 in DMA at 10°C, followed by coupling with the 7-aminocephem (II) by means of Et_3N in cold EtOAc/H_2O, affords amide (III) (1). Substitution of the allylic chloride of compound (III) with 4-[(N-Boc-aminoethyl)carbamoylamino]-1-methyl-5-tritylaminopyrazole (IV) in the presence of 1,3-bis(trimethylsilyl)urea (BSU) and KI in DMF then affords the protected pyrazolium adduct (V), which, after full deprotection with trifluoroacetic acid in anisole/CH_2Cl_2,can be isolated as the hydrogensulfate salt by treatment with H2SO4 in i-PrOH/H_2O (1, 2). Scheme 1. The pyrazolyl urea intermediate (IV) can be prepared as follows. Treatment of 5-amino-1-methylpyrazole (VI) with $NaNO_2$/HCl in water at 5°C gives the 4-nitrosopyrazole derivative (VII), which can be reduced to the diaminopyrazole (VIII) by catalytic hydrogenation over Pd/C in the presence of H_2SO_4. Selective acylation of the 4-amino group of compound (VIII) with phenyl chloroformate in the presence of NaOH in H_2O/dioxane at 10°C then yields the phenyl carbamate (IX). After protection of the free amine group of carbamate (IX) with chlorotriphenylmethane in the presence of Et_3N in THF, the resulting N-trityl derivative (X)can be coupled with N-Boc-ethylenediamine (XI) in the presence of Et_3N in DMF to afford pyrazolyl urea (IV).

Biological Activity Assay

The antibacterial activity of the CXA-201 or other compounds can be measured by the minimum inhibitory concentrations (MIC) of the compounds against various bacteria measured by using the broth microdilution method performed according to Clinical and Laboratory Standards Institute (CLSI) guidelines with modifications as

described below (CLSI guidelines can be derived from the CLSI document M7-A8 published in January 2009: "Methods for Dilution Antimicrobial Susceptibility Tests for Bacteria That Grow Aerobically; Approved Standard-Eighth Edition").

To prepare for MIC testing, individual colonies can be isolated by streaking frozen glycerol material containing Staphylococcus or Pseudomonas spp. onto rich, non-selective, tryptic soy agar containing 5% sheep's blood (TSAB), and incubated at 37°C for 18-24 hrs.

On the day of testing, primary cultures can be started by scraping off 5-10 colonies from the TSAB plates. The material can be suspended in ~5 mL of cation adjusted Mueller Hinton Broth (CAMHB) in 14 mL culture tubes and can be incubated at 37°C with aeration (200 rpm) for ~2 hrs until the OD600 was ≥0.1.

Inoculum cultures can be prepared by standardizing the primary cultures to OD600 = 0.1 and then adding 20 μL of the adjusted primary culture per 1 mL CAMHB for Pseudomonas and CAMHB plus 4% NaCl for MRSA so that the final inoculum density was ~10^5 colony forming units per milliliter. Diluted inoculum cultures can be used to inoculate 50 μL per well in 96 well broth microdilution assay plates. 50 μL of CAMHB that contained compound concentrations ranging from 64 – 0.06 μg/mL in two-fold dilutions can also be added to the broth microdilution assay plates for a final volume 100 μL per well, therefore final culture OD_{600} was approximately 0.001 and the final NaCl concentration for the MRSA strain was 2%.

Plates can be incubated for 18-20 hours at 37°C with aeration (200 rpm). Following incubation, growth can be confirmed visually placing plates over a viewing apparatus (stand with a mirror underneath) and then OD_{600} can be measured using a SpectraMax 340PC384 plate reader (Molecular Devices, Sunnyvale, CA). Growth was defined as turbidity that could be detected with the naked eye or achieving minimum OD_{600} of 0.1. MIC values were defined as the lowest concentration producing no visible turbidity.

The examples and illustrative embodiments described herein are provided by way of illustration, and do not constitute additional limitations on the scope of the claims. While some embodiments have been shown and described in the instant specification, the specification as ready by one of ordinary skill in the relevant arts also discloses various modifications and substitutions of embodiments explicitly disclosed

herein. The exemplary embodiments from the specification are not provided to read additional limitations into the claims.

CLAIMS

1. A method of treating an intrapulmonary infection comprising the step of intravenously administering about every 8 hours to a subject in need thereof a pharmaceutical composition comprising 3.0 g of ceftolozane.

2. The method of claim 1, wherein the pharmaceutical composition further comprises tazobactam.

3. The method of claim 2, wherein the pharmaceutical composition comprises ceftolozane and tazobactam and the infection comprises Gram-negative bacteria.

4. A method of treating an intrapulmonary infection comprising the step of administering a therapeutically effective amount of a pharmaceutical composition comprising ceftolozane.

5. The method of any one of claims 1-4, wherein the intrapulmonary infection includes an infection in the lung.

6. The method of any one of claims 1-4, wherein the intrapulmonary infection is pneumonia.

7. The method of any one of claims 1-4, wherein the intrapulmonary infection is nosocomial pneumonia.

8. The method of any one of claims 1-8, wherein the pharmaceutical composition is parenterally administered.

9. The method of any one of claims 1-8, wherein the pharmaceutical composition is intravenously administered.

10. The method of any one of claims 1-8, wherein the pharmaceutical composition is intravenously administered about once every 8 hours as an infusion.

11. The method of claim 10, wherein the pharmaceutical composition is intravenously administered as a 60-minute infusion.

12. The method of any one of claims 1-11, wherein the infection comprises *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof.

13. The method of any one of claims 1-11, wherein the infection comprises *Pseudomonas aeruginosa*.

14. The method of any one of claims 1-13, wherein the infection comprises a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of ≤ 8μg/ml.

15. The method of any one of claims 1-13, wherein the infection comprises a pathogen with minimum inhibitory concentration for ceftolozane of ≤ 8μg/ml.

16. A method of providing tazobactam or ceftolozane in the epithelial lining fluid of a subject in an amount effective to treat an intrapulmonary infection, comprising the step of intravenously administering to the subject a pharmaceutical composition comprising ceftolozane.

17. The method of claim 16, wherein the pharmaceutical composition further comprises tazobactam and the pharmaceutical composition is CXA-201.

18. The method of any one of claims 16-17, wherein the method comprises administering about 1.5 g of ceftolozane and tazobactam every 8 hours.

19. The method of any one of claims 16-18, wherein the amount of the ceftolozane in the epithelial lining fluid of the subject effective to treat an intrapulmonary infection is at least about 8 μg/ml.

20. The method of any one of claims 17-19, wherein the ELF concentration of ceftolozane in the ELF reaches at least about 8 μg/ml after administration of the pharmaceutical composition.

21. The method of any one of claims 17-20, wherein the subject is a human having, or believed to be at risk of having, nosocomial pneumonia.

22. The method of claim 21, wherein the patient has ventilator acquired pneumonia or hospital acquired pneumonia.

23. Use of ceftolozane in the manufacture of a medicament for the treatment of an intrapulmonary infection comprising intravenously administering a pharmaceutical composition comprising 3.0 g of the ceftolozane every 8 hours to a subject in need thereof.

24. The use of claim 23, wherein the pharmaceutical composition further comprises tazobactam.

25. The use of claim 24, wherein the pharmaceutical composition comprises ceftolozane and tazobactam and the infection comprises Gram-negative bacteria.

26. Use of ceftolozane in the manufacture of a medicament for the treatment of an intrapulmonary infection comprising administering a therapeutically effective amount of a pharmaceutical composition comprising the ceftolozane.

27. The use of any one of claims 23-26, wherein the intrapulmonary infection includes an infection in the lung.

28. The use of any one of claims 23-26, wherein the intrapulmonary infection is pneumonia.

29. The use of any one of claims 23-26, wherein the intrapulmonary infection is nosocomial pneumonia.

30. The use of any one of claims 23-29, wherein the pharmaceutical composition is parenterally administered.

31. The use of any one of claims 23-29, wherein the pharmaceutical composition is intravenously administered.

32. The use of any one of claims 23-29, wherein the pharmaceutical composition is intravenously administered about once every 8 hours as an infusion.

33. The use of claim 32, wherein the pharmaceutical composition is intravenously administered as a 60-minute infusion.

34. The use of any one of claims 23-33, wherein the infection comprises *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof.

35. The use of any one of claims 23-33, wherein the infection comprises *Pseudomonas aeruginosa*.

36. The use of any one of claims 23-35, wherein the infection comprises a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of $\leq$ 8μg/ml.

37. The use of any one of claims 23-35, wherein the infection comprises a pathogen with minimum inhibitory concentration for ceftolozane of $\leq$ 8μg/ml.

38. Use of ceftolozane in the manufacture of a medicament for the treatment of an intrapulmonary infection comprising intravenously administering a

pharmaceutical composition comprising the ceftolozane, wherein tazobactam or ceftolozane is provided in the epithelial lining fluid of a subject in an amount effective to treat the intrapulmonary infection.

39. The use of claim 38, wherein the pharmaceutical composition further comprises tazobactam and the pharmaceutical composition is CXA-201.

40. The use of any one of claims 38-39, wherein the use comprises administering about 1.5 g of ceftolozane and tazobactam in total every 8 hours.

41. The use of any one of claims 38-40, wherein the amount of the ceftolozane in the epithelial lining fluid of the subject effective to treat an intrapulmonary infection is at least about 8 μg/ml.

42. The use of any one of claims 38-41, wherein the ELF concentration of ceftolozane in the ELF reaches at least about 8 μg/ml after administration of the pharmaceutical composition.

43. The use of any one of claims 38-42, wherein the subject is a human having, or believed to be at risk of having, nosocomial pneumonia.

44. The use of claim 43, wherein the patient has ventilator acquired pneumonia or hospital acquired pneumonia.

45. Ceftolozane, for use in a method of treating an intrapulmonary infection.

46. The ceftolozane of claim 45, for use in a method of treating an intrapulmonary infection, comprising administration of ceftolozane in combination with tazobactam.

47. Tazobactam, for use in a method of treating an intrapulmonary infection, comprising administration of tazobactam in combination with ceftolozane.

48. Ceftolozane and tazobactam, as a combined preparation for simultaneous, separate or sequential use in a method of treating an intrapulmonary infection.

49. The ceftolozane of any one of claims 45-46, the tazobactam of claim 47 or the ceftolazane and tazobactam of claim 48, wherein the ceftolozane and/or tazobactam is parenterally administered.

50. The ceftolozane of any one of claims 45-46 and 49, the tazobactam of any one of claims 47 and 49, or the ceftolazane and tazobactam of any one of claims 48-49, wherein the ceftolozane and/or tazobactam is intravenously administered.

51. The ceftolozane of any one of claims 45-46 and 49, the tazobactam of any one of claims 47 and 49, or the ceftolazane and tazobactam of any one of claims 48-49, wherein the ceftolozane and/or tazobactam is administered about once every 8 hours as an infusion.

52. The ceftolozane, the tazobactam, or the ceftolazane and tazobactam of claim 51, wherein the ceftolozane and/or tazobactam is intravenously administered as a 60-minute infusion.

53. The ceftolozane of any one of claims 45-46 and 49-52, the tazobactam of any one of claims 47 and 49-52, or the ceftolazane and tazobactam of any one of claims 48-52, wherein the intrapulmonary infection comprises an infection in the lung.

54. The ceftolozane of any one of claims 45-46 and 49-52, the tazobactam of any one of claims 47 and 49-52, or the ceftolazane and tazobactam of any one of claims 48-52, wherein the intrapulmonary infection is pneumonia.

55. The ceftolozane of any one of claims 45-46 and 49-52, the tazobactam of any one of claims 47 and 49-52, or the ceftolazane and tazobactam of any one of claims 48-52, wherein the intrapulmonary infection is nosocomial pneumonia.

56. The ceftolozane of any one of claims 45-46 and 49-55, the tazobactam of any one of claims 47 and 49-55, or the ceftolazane and tazobactam of any one of claims 48-55, wherein the intrapulmonary infection comprises *Pseudomonas aeruginosa, Enterobacteriaceae,* or a combination thereof.

57. The ceftolozane of any one of claims 45-46 and 49-56, the tazobactam of any one of claims 47 and 49-56, or the ceftolazane and tazobactam of any one of claims 48-56, wherein the intrapulmonary infection comprises *Pseudomonas aeruginosa*.

58. The ceftolozane of any one of claims 45-46 and 49-57, the tazobactam of any one of claims 47 and 49-57, or the ceftolazane and tazobactam of any one of claims 48-57, wherein the intrapulmonary infection comprises a pathogen with minimum inhibitory concentration for ceftolozane and tazobactam of $\leq 8\mu g/ml$.

59. The ceftolozane of any one of claims 45-46 and 49-57, the tazobactam of any one of claims 47 and 49-57, or the ceftolazane and tazobactam of any one of claims 48-57, wherein the intrapulmonary infection comprises a pathogen with minimum inhibitory concentration for ceftolozane of $\leq 8\mu g/ml$.

60. Ceftolozane for use in a method of providing tazobactam or ceftolozane in the epithelial lining fluid of a subject in an amount effective to treat an intrapulmonary infection, comprising the step of intravenously administering ceftolozane.

61. The ceftolozane of claim 60, wherein the ceftolozane is administered in combination with tazobactam.

62. The ceftolozane of claim 61, comprising administration of CXA-201.

63. The ceftolozane of claim 61 or 62, comprising administration of about 1.5 g of ceftolozane and tazobactam in total every 8 hours.

64. The ceftolozane of any one of claims 60-63, wherein the amount of the ceftolozane in the ELF of the subject effective to treat an intrapulmonary infection is at least about 8 μg/ml.

65. The ceftolozane of any one of claims 60-64, wherein the ELF concentration of ceftolozane in the ELF reaches at least about 8 μg/ml after administration of the ceftolozane.

66. The ceftolozane of any one of claims 60-65, wherein the subject is a human having, or believed to be at risk of having, nosocomial pneumonia.

67. The ceftolozane of claim 66, wherein the patient has ventilator acquired pneumonia or hospital acquired pneumonia.

68. The method of any one of claims 1-22, the use of any one of claims 23-44, the ceftolozane of any one of claims 45-46 and 49-67, the tazobactam of any one of claims 47 and 49-59, or the ceftolazane and tazobactam of any one of claims 48-59, wherein the ceftolozane is CXA-101 in its free-base form.

69. The method of any one of claims 1-22, the use of any one of claims 23-44, the ceftolozane of any one of claims 45-46 and 49-67, the tazobactam of any one of claims 47 and 49-59, or the ceftolazane and tazobactam of any one of claims 48-59, wherein the ceftolozane is CXA-101 in its salt form.

70. The method, the use, the ceftolozane, the tazobactam, or the ceftolazane and tazobactam of claim 69 wherein the ceftolozane is CXA-101 is in its hydrogen sulfate form.

71. The method of claim 1, wherein the treatment comprises administering ceftolozane every 8 hours.

72. The use of claim 26, wherein the pharmaceutical composition further comprises tazobactam.

Figure 1

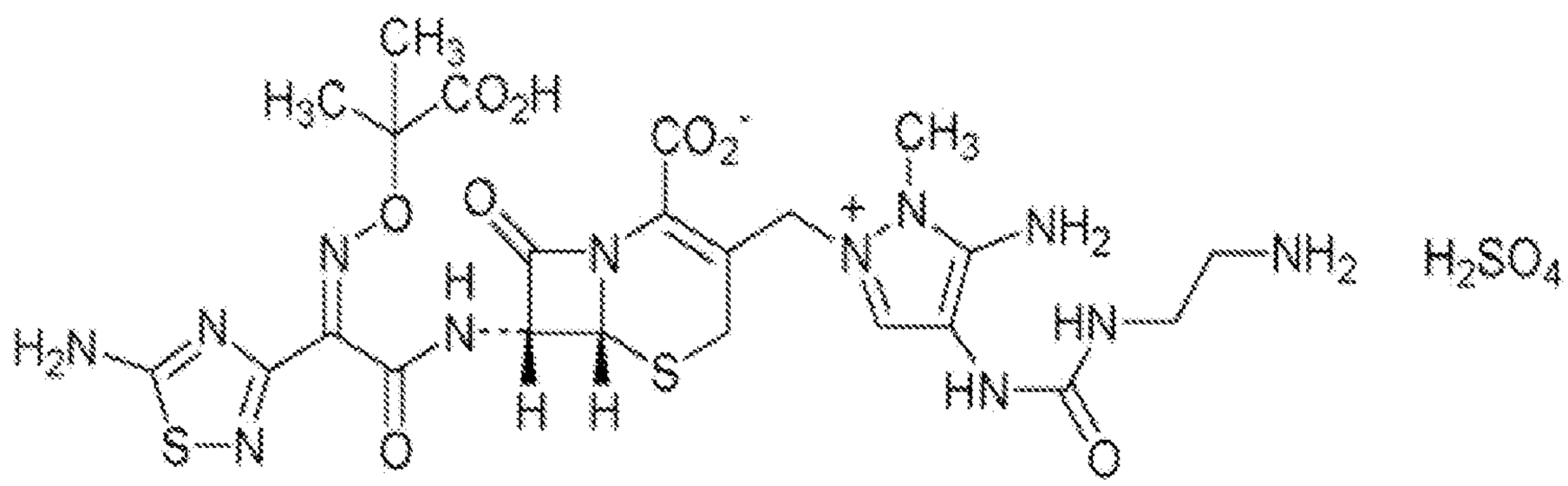


Figure 2A

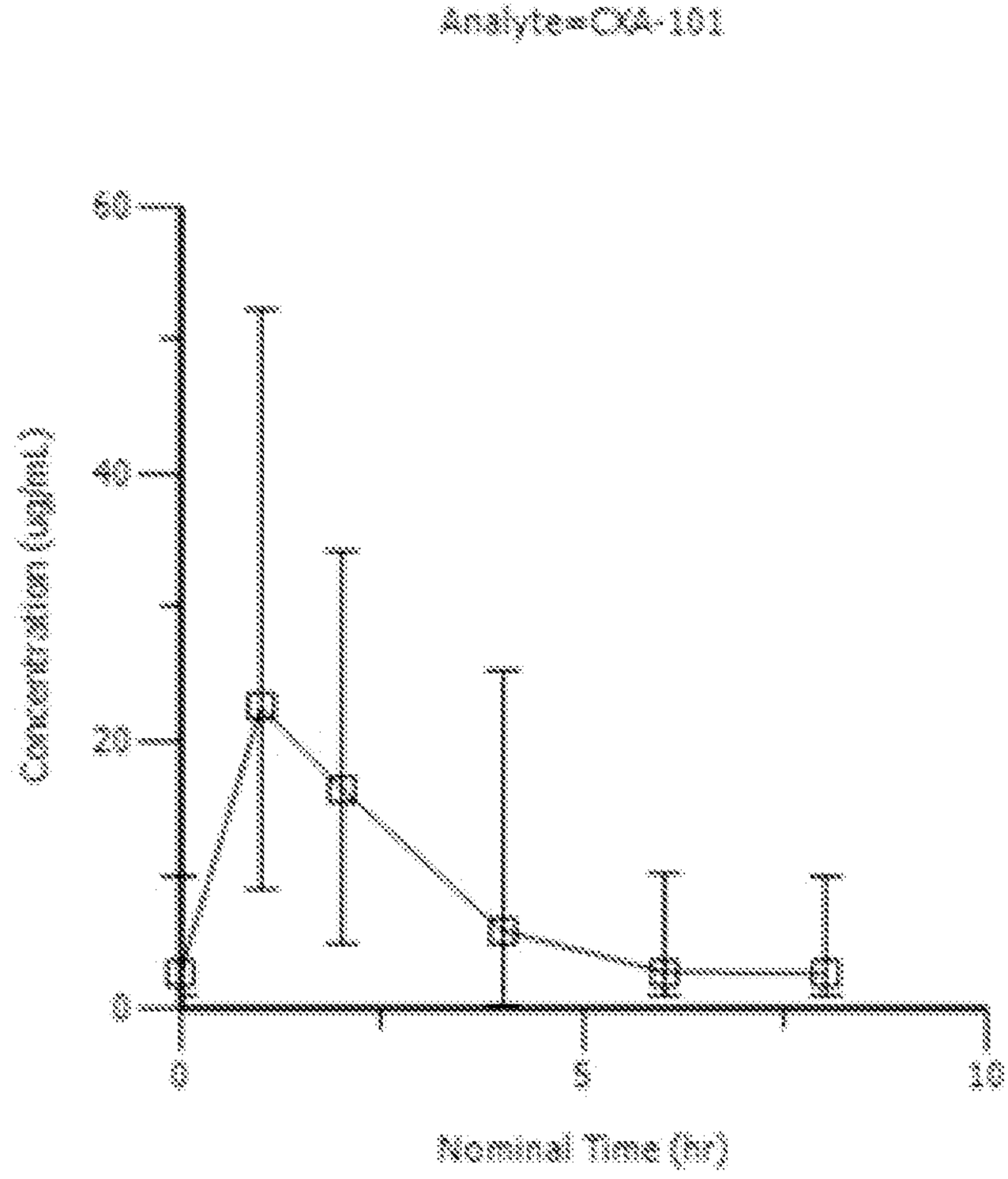

Analyte=CXA-101
60
40
20
0
Concentration (ug/mL)
0
5
10
Nominal Time (hr)

Figure 2B

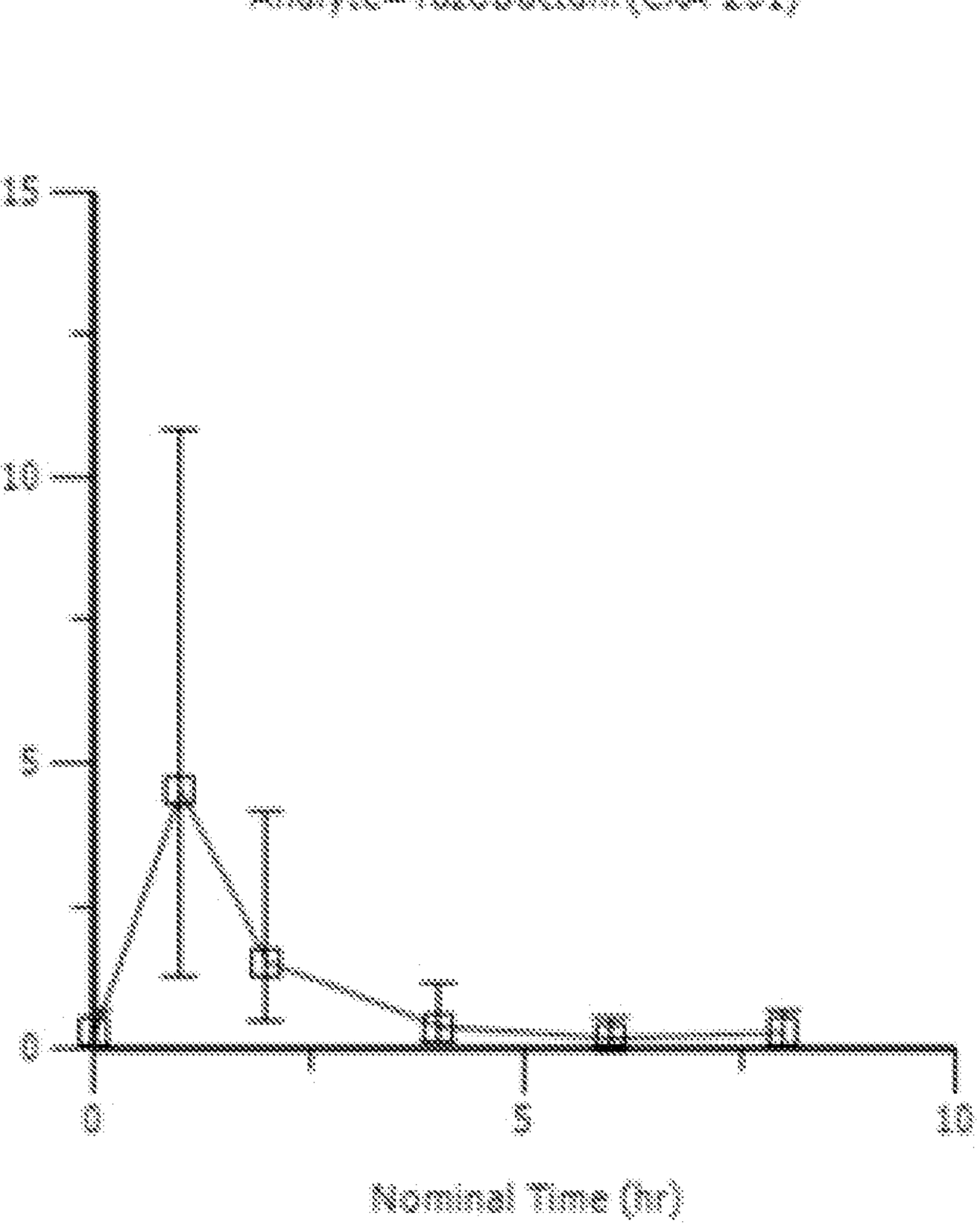

Analyte=Tazobactam (CX4-201)
Concentration (ug/mL)
15
10
5
0
0
5
10
Nominal Time (hr)

Figure 3A

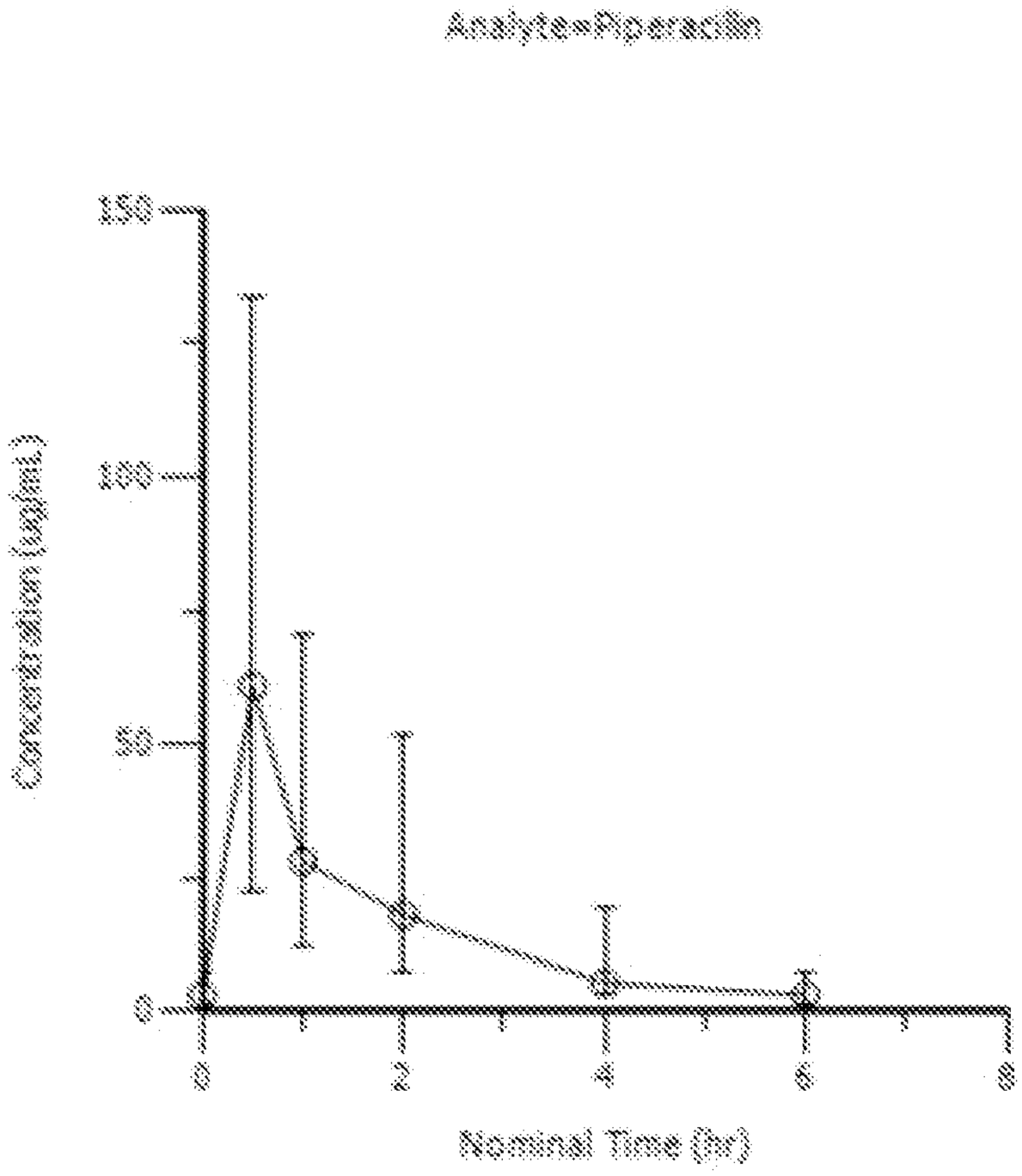

Analyte-Aperachlor
150
100
50
0
Concentration (ug/mL)
0
2
4
6
8
Nominal Time (hr)

Figure 3B

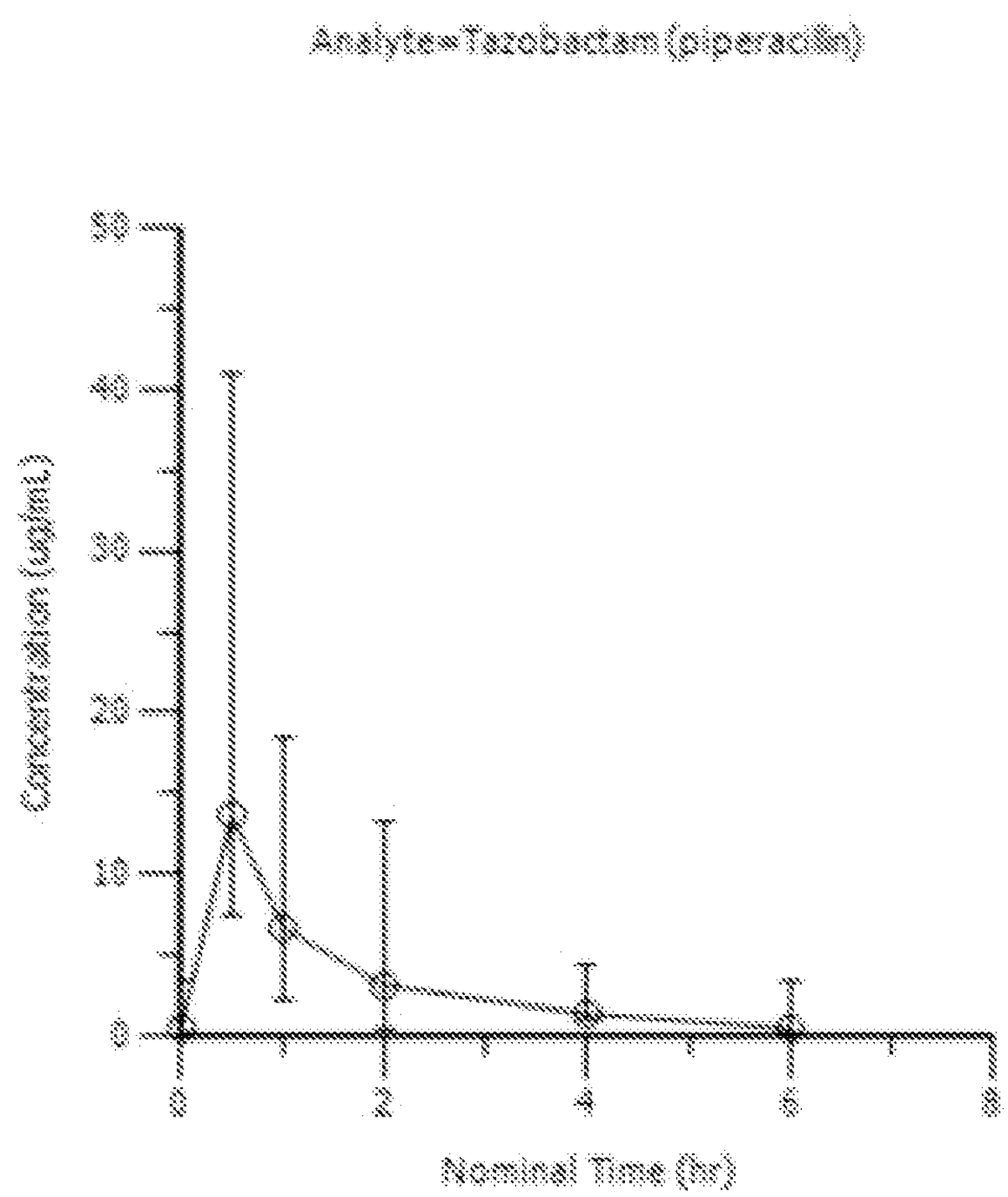
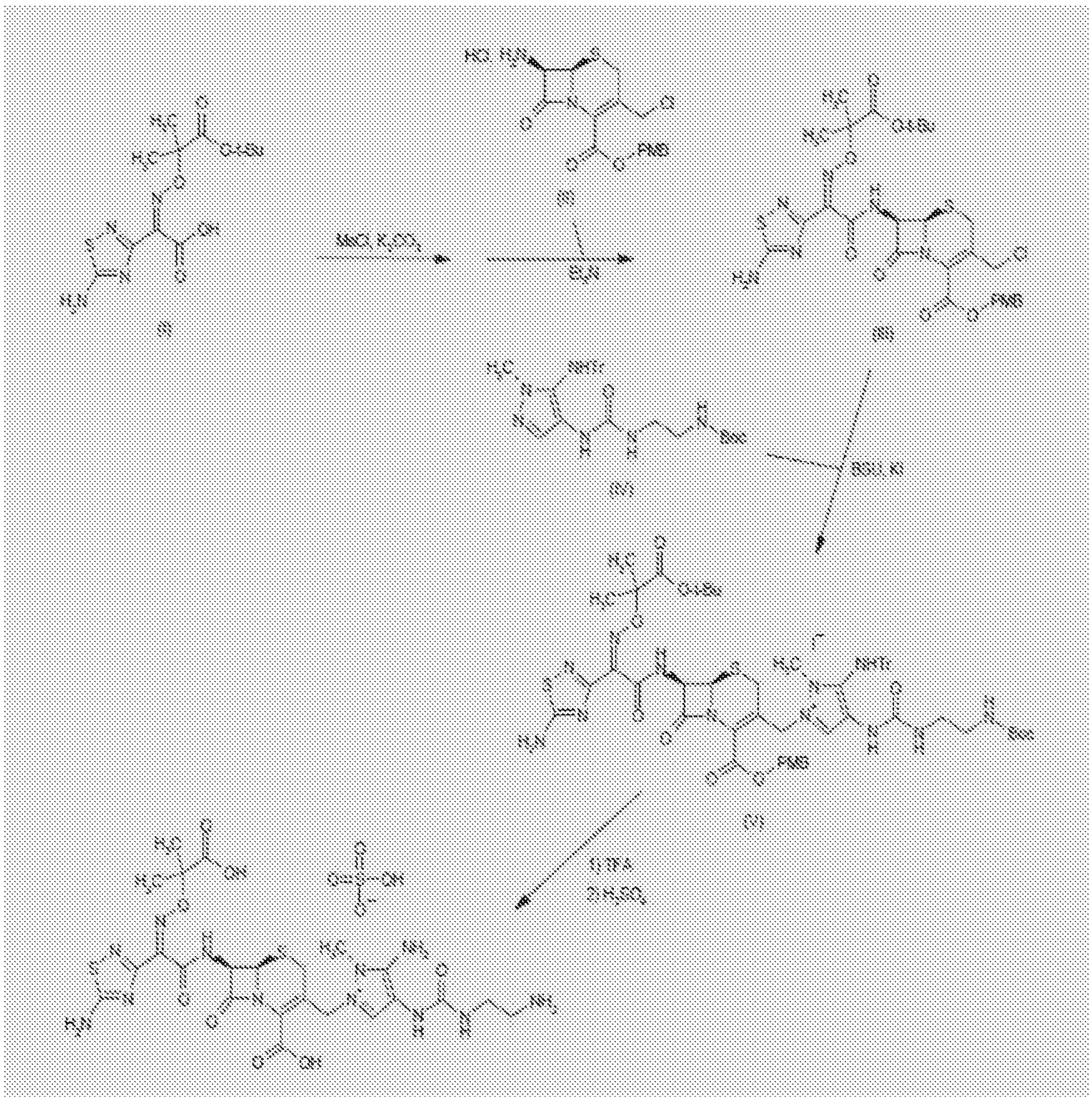
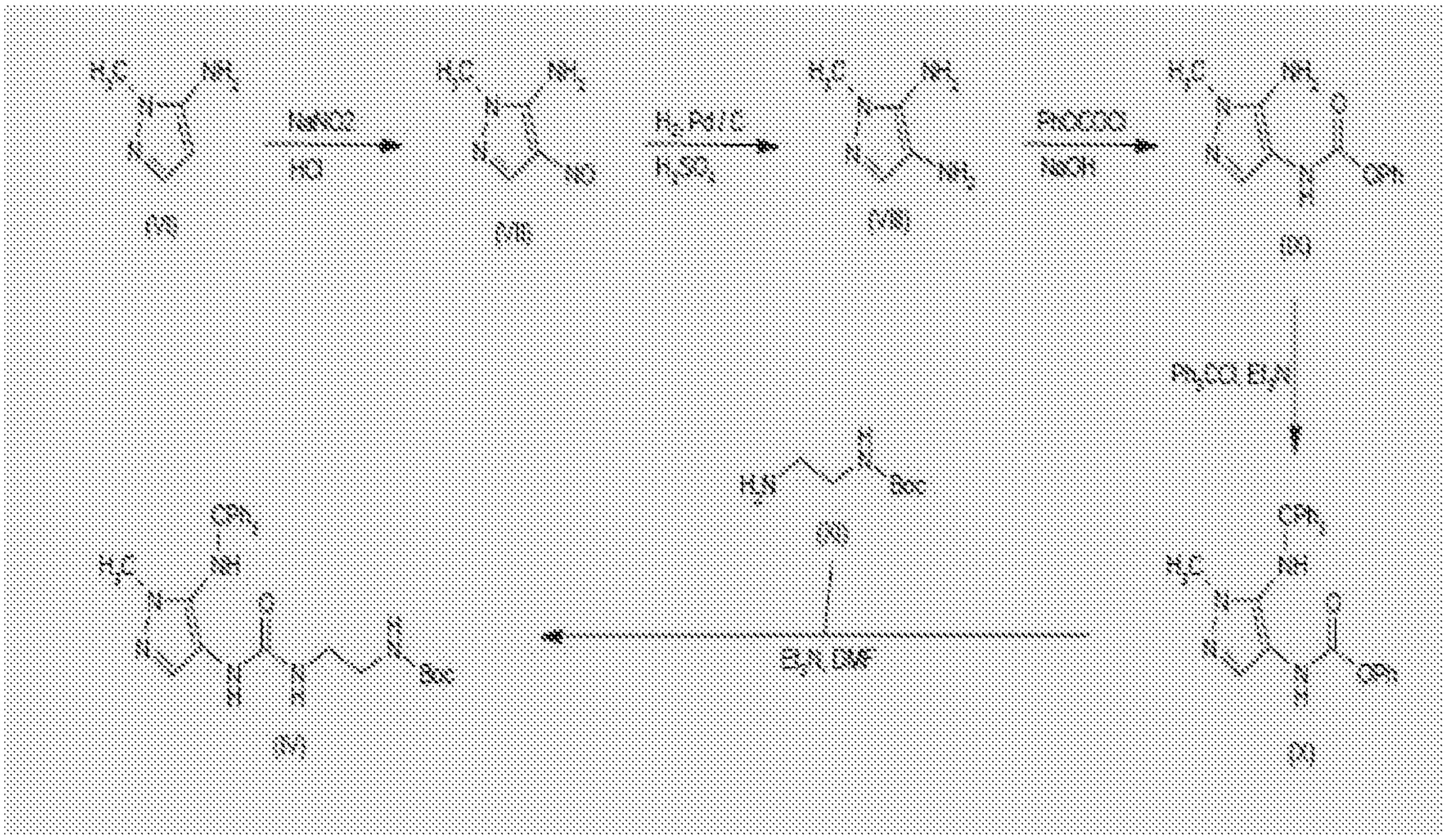

Analyte=Tazobactam (piperacillin)
Concentration (ug/mL)
0
10
20
30
0
2
4
6
8
Nominal Time (hr)

Figure 4A



Scheme 1

Figure 4B



Scheme 2