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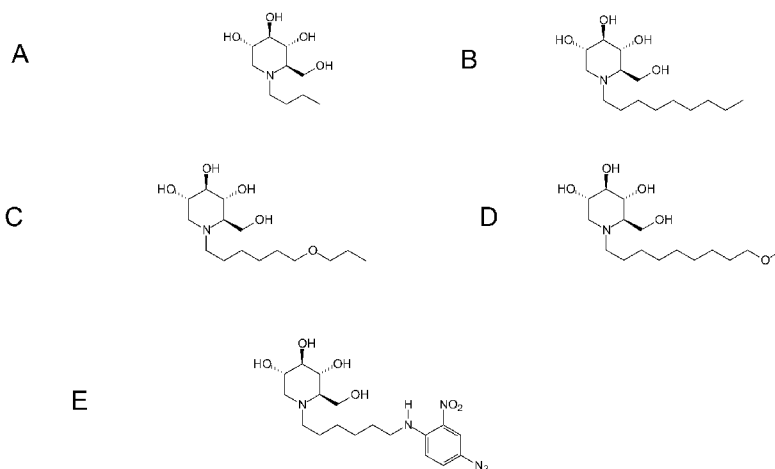
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(54) Title: IMINOSUGARS AND METHODS OF TREATING FILOVIRAL DISEASES

FIGURES 1(A)-(E)



(57) Abstract: Provided are methods of treating a disease or condition caused by or associated with a virus belonging to the Filoviridae family using iminosugars, such as DNJ derivatives.

IMINOSUGARS AND METHODS OF TREATING FILOVIRAL DISEASES

RELATED APPLICATIONS

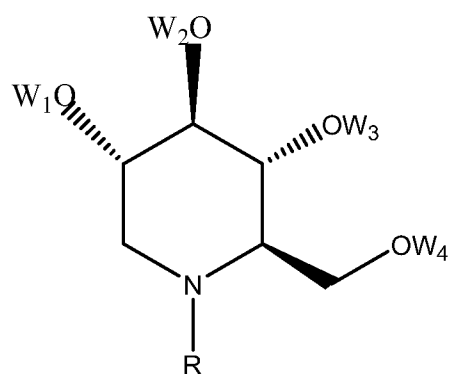
The present application claims priority to U.S. provisional application no. 61/272,253 filed September 4, 2009 and U.S. provisional application no. 61/282,507 filed February 22, 2010, both of which are incorporated herein by reference in their entirety.

FIELD

The present application relates to iminosugars and methods of treating viral infections with iminosugars and, in particular, to the use of iminosugars for treatment and prevention of viral infections caused by or associated with a virus belonging to the Filoviridae family.

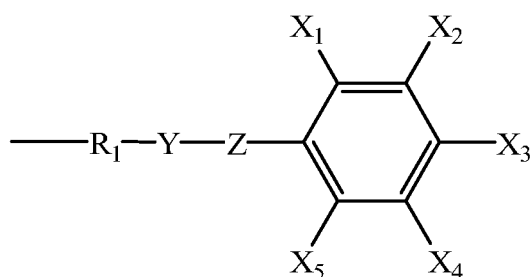
SUMMARY

One embodiment is a method of treating or preventing a disease or condition caused by or associated with a virus belonging to the Filoviridae family, which method comprises administering to a subject in need thereof an effective amount of a compound of the formula,



, or a pharmaceutically acceptable salt thereof, wherein R is

either selected from substituted or unsubstituted alkyl groups, substituted or unsubstituted cycloalkyl groups, substituted or unsubstituted aryl groups, or substituted or unsubstituted oxaalkyl groups; or wherein R is



R_1 is a substituted or unsubstituted alkyl group;

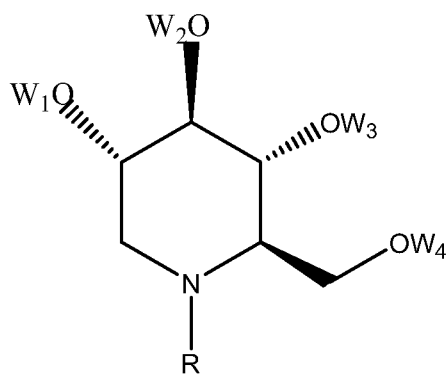
X_{1-5} are independently selected from H, NO_2 , N_3 , or NH_2 ;

Y is absent or is a substituted or unsubstituted C_1 -alkyl group, other than carbonyl; and

Z is selected from a bond or NH; provided that when Z is a bond, Y is absent, and provided that when Z is NH, Y is a substituted or unsubstituted C_1 -alkyl group, other than carbonyl; and

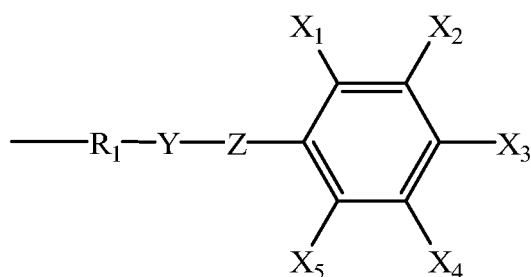
wherein W_{1-4} are independently selected from hydrogen, substituted or unsubstituted alkyl groups, substituted or unsubstituted haloalkyl groups, substituted or unsubstituted alkanoyl groups, substituted or unsubstituted aroyl groups, or substituted or unsubstituted haloalkanoyl groups.

Another embodiment is a method of inhibiting infectivity of a cell infected with a virus belonging to the Filoviridae family, which method comprises contacting a cell infected with a virus belonging to the Filoviridae family with an effective amount of a compound of the formula,



, or a pharmaceutically acceptable salt thereof, wherein R is

either selected from substituted or unsubstituted alkyl groups, substituted or unsubstituted cycloalkyl groups, substituted or unsubstituted aryl groups, or substituted or unsubstituted oxaalkyl groups; or wherein R is



R_1 is a substituted or unsubstituted alkyl group;

X_{1-5} are independently selected from H, NO_2 , N_3 , or NH_2 ;

Y is absent or is a substituted or unsubstituted C_1 -alkyl group, other than carbonyl; and

Z is selected from a bond or NH; provided that when Z is a bond, Y is absent, and provided that when Z is NH, Y is a substituted or unsubstituted C_1 -alkyl group, other than carbonyl; and

wherein W_{1-4} are independently selected from hydrogen, substituted or unsubstituted alkyl groups, substituted or unsubstituted haloalkyl groups, substituted or unsubstituted alkanoyl groups, substituted or unsubstituted aroyl groups, or substituted or unsubstituted haloalkanoyl groups, wherein said contacting reduces the infectivity of the cell.

DRAWINGS

Figures 1(A)-(E) present chemical formulas of the following iminosugars: A) *N*-Butyl deoxynojirimycin (NB-DNJ or UV-1); B) *N*-Nonyl deoxynojirimycin (NN-DNJ or UV-2); C) *N*-(7-Oxadecyl)deoxynojirimycin (N7-O-DNJ or UV-3); D) *N*-(9-Methoxynonyl) deoxynojirimycin (N9-DNJ or UV-4); E) *N*-(*N*-{4'-azido-2'-nitrophenyl}-6-aminoethyl)deoxynojirimycin (NAP-DNJ or UV-5).

Figure 2 is a synthesis scheme for NN-DNJ.

Figures 3A-D illustrate synthesis of N7-O-DNJ. In particular, Figure 3A shows a sequence of reactions leading to N7-O-DNJ; Figure 3B illustrates preparation of 6-propyloxy-1-hexanol; Figure 3C illustrates preparation of 6-propyloxy-1-hexanal; Figure 3D illustrates synthesis of N7-O-DNJ.

Figures 4A-C relate to synthesis of *N*-(9-Methoxynonyl) deoxynojirimycin. In particular, Figure 4A illustrates preparation of 9-methoxy-1-nonanol; Figure 4B illustrates preparation of 9-methoxy-1-nonanal; Figure 4C illustrates synthesis of *N*-(9-Methoxynonyl) deoxynojirimycin.

Figure 5 provides data for inhibition of infectivity of Ebola Zaire and Marburg viruses for N9-DNJ (UV-4) and NAP-DNJ (UV-5).

Figure 6 presents effects of 10 day administration of UV-5 on survival of mice infected with Ebola virus.

Figure 7 presents *in vivo* safety data for UV-4 and UV-5.

Figure 8 presents survival data for mice challenged with Ebola Zaire virus (left) and Marburg virus (right) after administering UV-5.

DETAILED DESCRIPTION

Related Documents

The following patent documents, which are all incorporated herein by reference in their entirety, may be useful for understanding the present disclosure:

- 1) US patent no. 6,545,021;
- 2) US patent no. 6,809,803;
- 3) US patent no. 6,689,759;
- 4) US patent no. 6,465,487;
- 5) US patent no. 5,622,972;
- 6) US patent application no. 12/656,992 filed February 22, 2010;
- 7) US patent application no. 12/656,993 filed February 22, 2010;
- 8) US patent application no. 12/813,882 filed June 11, 2010;
- 9) US patent provisional application no. 61/282,507 filed February 22, 2010;
- 10) US patent provisional application no. 61/272,252 filed September 4, 2009;
- 11) US provisional application no. 61/272,253 filed September 4, 2009;
- 12) US provisional application no. 61/272,254 filed September 4, 2009;
- 13) US provisional application no. 61/282,508 filed February 22, 2010;
- 14) US provisional application no. 61/353,935 filed June 11, 2010.

Definition of terms

Unless otherwise specified, “a” or “an” means “one or more.”

As used herein, the term “viral infection” describes a diseased state, in which a virus invades a healthy cell, uses the cell’s reproductive machinery to multiply or replicate and ultimately lyse the cell resulting in cell death, release of viral particles and the infection of other cells by the newly produced progeny viruses. Latent infection by certain viruses is also a possible result of viral infection.

As used herein, the term “treating or preventing viral infection” means to inhibit the replication of the particular virus, to inhibit viral transmission, or to prevent the virus from establishing itself in its host, and to ameliorate or alleviate the symptoms of the disease caused by the viral infection. The treatment is considered therapeutic if there is a reduction in viral load, decrease in mortality and/or morbidity.

IC50 or IC90 (inhibitory concentration 50 or 90) is a concentration of a therapeutic agent, such as an iminosugar, used to achieve 50% or 90% reduction of viral load, respectively.

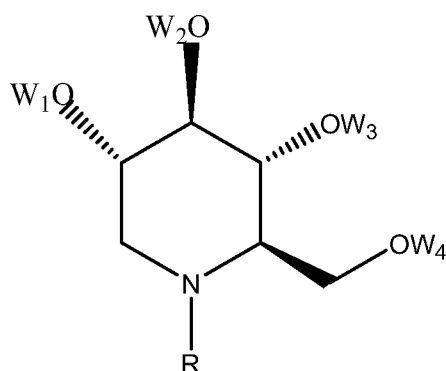
Disclosure

The present inventors discovered that certain iminosugars, such as deoxynojirimycin derivatives, may be effective against viruses belonging to the Filoviridae family, which are also known as filoviruses.

In particular, the deoxynojirimycin derivatives may be useful for treating or preventing a disease or condition caused by or associated with a virus belonging to the Filoviridae family.

The Filoviridae family includes the Ebolavirus genus and the Marburgvirus genus. The Ebolavirus genus includes Zaïre virus, Bundibugyo Ebola virus, Ivory Coast Ebola virus, Reston Ebola virus and Sudan Ebola virus, while the Marburgvirus genus includes Lake Victoria Marburg virus. Diseases that are caused or associated with filoviruses include Ebola hemorrhagic fever and Marburg hemorrhagic fever.

In many embodiments, the iminosugar may be N-substituted deoxynojirimycin. In some embodiments, such N-substituted deoxynojirimycin may be a compound of the following formula:



where W_{1-4} are independently selected from hydrogen, substituted or unsubstituted alkyl groups, substituted or unsubstituted haloalkyl groups, substituted or unsubstituted alkanoyl groups, substituted or unsubstituted aroyl groups, or substituted or unsubstituted haloalkanoyl groups.

In some embodiments, R may be selected from substituted or unsubstituted alkyl groups, substituted or unsubstituted cycloalkyl groups, substituted or unsubstituted aryl groups, or substituted or unsubstituted oxaalkyl groups.

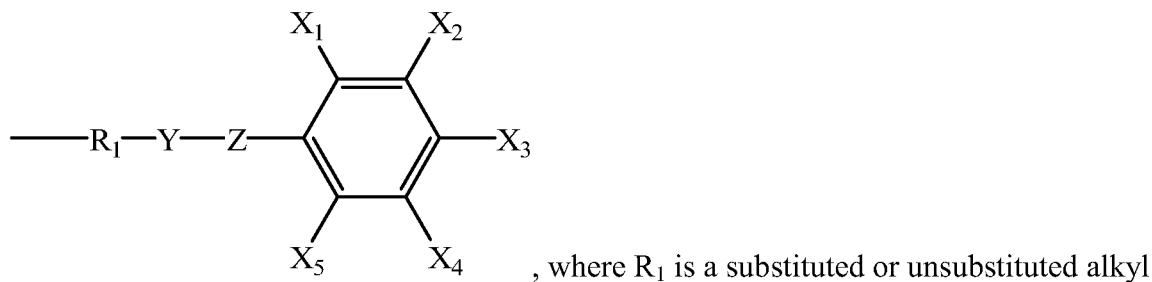
In some embodiments, R may be substituted or unsubstituted alkyl groups and/or substituted or unsubstituted oxaalkyl groups comprise from 1 to 16 carbon atoms, from 4 to 12 carbon atoms or from 8 to 10 carbon atoms. The term “oxaalkyl” refers to an alkyl derivative, which may contain from 1 to 5 or from 1 to 3 or from 1 to 2 oxygen atoms. The term “oxaalkyl” includes hydroxyterminated and methoxyterminated alkyl derivatives.

In some embodiments, R may be selected from, but is not limited to $-(CH_2)_6OCH_3$, $-(CH_2)_6OCH_2CH_3$, $-(CH_2)_6O(CH_2)_2CH_3$, $-(CH_2)_6O(CH_2)_3CH_3$, $-(CH_2)_2O(CH_2)_5CH_3$, $-(CH_2)_2O(CH_2)_6CH_3$; $-(CH_2)_2O(CH_2)_7CH_3$; $-(CH_2)_9-OH$; $-(CH_2)_9OCH_3$.

In some embodiments, R may be branched or unbranched, substituted or unsubstituted alkyl group, which may contain up to 20 carbon atoms. In some embodiments, the alkyl group may be C2-C12 or C3-C7 alkyl group.

In certain embodiments, the alkyl group may be a long chain alkyl group, which may be C6-C20 alkyl group; C8-C16 alkyl group; or C8-C10 alkyl group. In some embodiments, R may be a long chain oxaalkyl group, i.e., a long chain alkyl group, which may contain from 1 to 5 or from 1 to 3 or from 1 to 2 oxygen atoms.

In some embodiments, R may have the following formula



group;

X₁₋₅ are independently selected from H, NO₂, N₃, or NH₂;

Y is absent or is a substituted or unsubstituted C₁-alkyl group, other than carbonyl; and

Z is selected from a bond or NH; provided that when Z is a bond, Y is absent, and provided that when Z is NH, Y is a substituted or unsubstituted C₁-alkyl group, other than carbonyl.

In some embodiments, Z is NH and R₁-Y is a substituted or unsubstituted alkyl group, such as C₂-C₂₀ alkyl group or C₄-C₁₂ alkyl group or C₄-C₁₀ alkyl group.

In some embodiments, X₁ is NO₂ and X₃ is N₃. In some embodiments, each of X₂, X₄ and X₅ is hydrogen.

In some embodiments, the iminosugar may be a DNJ derivative disclosed in U.S. Patent application publication no. 2007/0275998, which is incorporated herein by reference.

In some embodiments, the iminosugar may be one of the compounds presented in Figure 1.

Methods of synthesizing deoxynojirimycin derivatives are disclosed, for example, in U.S.

Patent nos. 5,622,972, 5,200,523, 5,043,273, 4,994,572, 4,246,345, 4,266,025, 4,405,714, and 4,806,650 and U.S. Patent application publication no. 2007/0275998, which are all incorporated herein by reference.

In some embodiments, the iminosugar may be in a form of a salt derived from an inorganic or organic acid. Pharmaceutically acceptable salts and methods for preparing salt forms are disclosed, for example, in Berge et al. (*J. Pharm. Sci.* 66:1-18, 1977). Examples of appropriate salts include but are not limited to the following salts: acetate, adipate, alginate, citrate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, camphorate, camphorsulfonate, digluconate, cyclopentanepropionate, dodecylsulfate, ethanesulfonate, glucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, fumarate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethanesulfonate, lactate, maleate, methanesulfonate, nicotinate, 2-naphthalenesulfonate, oxalate, palmoate, pectinate,

persulfate, 3-phenylpropionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate, mesylate, and undecanoate.

In some embodiments, the iminosugar may also be used in a form of a prodrug. Prodrug of DNJ derivatives, such as the 6-phosphorylated DNJ derivatives, are disclosed in U.S. Patents nos. 5,043,273 and 5,103,008.

In some embodiments, the iminosugar may be used as a part of a composition, which further comprises a pharmaceutically acceptable carrier and/or a component useful for delivering the composition to an animal. Numerous pharmaceutically acceptable carriers useful for delivering the compositions to a human and components useful for delivering the composition to other animals such as cattle are known in the art. Addition of such carriers and components to the composition of the invention is well within the level of ordinary skill in the art.

In some embodiments, the pharmaceutical composition may consist essentially of *N*-substituted deoxynojirimycin, which may mean that the *N*-substituted deoxynojirimycin is the only active ingredient in the composition.

Yet in some embodiments, *N*-substituted deoxynojirimycin may be administered with one or more additional antiviral compounds.

In some embodiments, the treatment or prevention of the disease or condition caused by or associated with a virus belonging to the Filoviridae family may be performed without administering *N*-(phosphonoacetyl)-*L*-aspartic acid to the subject, to whom the iminosugar is being administered. *N*-(phosphonoacetyl)-*L*-aspartic acid is disclosed, for example, in U.S. patent no. 5,491,135.

In some embodiments, the iminosugar may be used in a liposome composition, such as those disclosed in US publications nos. 2008/0138351 and 2009/0252785 as well as in US application No. 12/732630 filed March 26, 2010.

The iminosugar, such as a DNJ derivative, may be administered to a cell or an animal affected by a virus. The iminosugar may inhibit morphogenesis of the virus, or it may treat the individual. The treatment may reduce, abate, or diminish the virus infection in the animal.

Animals that may be infected with a filovirus include primates, such as monkeys and humans.

The amount of iminosugar administered to an animal or to an animal cell to the methods of the invention may be an amount effective to inhibit the morphogenesis of a filovirus. The term "inhibit" as used herein may refer to the detectable reduction and/or elimination of a biological activity exhibited in the absence of the iminosugar. The term "effective amount" may refer to that amount of the iminosugar necessary to achieve the indicated effect. The term "treatment" as used herein may refer to reducing or alleviating symptoms in a subject, preventing symptoms from worsening or progressing, inhibition or elimination of the causative agent, or prevention of the infection or disorder related to the filovirus in a subject who is free therefrom.

Thus, for example, treatment of the disease caused by or associated with a virus may include destruction of the infecting agent, inhibition of or interference with its growth or maturation, and neutralization of its pathological effects. The amount of the iminosugar which may be administered to the cell or animal is preferably an amount that does not induce toxic effects which outweigh the advantages which accompany its administration.

Actual dosage levels of active ingredients in the pharmaceutical compositions may vary so as to administer an amount of the active compound(s) that is effective to achieve the desired therapeutic response for a particular patient.

The selected dose level may depend on the activity of the iminosugar, the route of administration, the severity of the condition being treated, and the condition and prior medical history of the patient being treated. However, it is within the skill of the art to start doses of the compound(s) at levels lower than required to achieve the desired therapeutic effect and to gradually increase the dosage until the desired effect is achieved. If desired, the effective daily dose may be divided into multiple doses for purposes of administration, for example, two to four doses per day. It will be understood, however, that the specific dose level for any particular patient can depend on a variety of factors, including the body weight, general health, diet, time and route of administration and combination with other therapeutic agents and the severity of the condition or disease being treated. The adult human daily dosage may range from between about one microgram to about one gram, or from between about 10 mg and 100 mg, of the iminosugar per 10 kilogram body weight. In some embodiments, a total daily dose may be from 0.1 mg/kg body weight to 100 mg/kg body weight or from 1 mg/kg body weight to 60 mg/kg body weight or from 2 mg/kg body weight

to 50 mg/kg body weight or from 3 mg/kg body weight to 30 mg/kg body weight. The daily dose may be administered over one or more administering events over day. For example, in some embodiments, the daily dose may be distributed over two (BID) administering events per day, three administering events per day (TID) or four administering events (QID). In certain embodiments, a single administering event dose ranging from 1 mg/kg body weight to 10 mg/kg body weight may be administered BID or TID to a human making a total daily dose from 2 mg/kg body weight to 20 mg/kg body weight or from 3 mg/kg body weight to 30 mg/kg body weight. Of course, the amount of the iminosugar which should be administered to a cell or animal may depend upon numerous factors well understood by one of skill in the art, such as the molecular weight of the iminosugar and the route of administration.

Pharmaceutical compositions that are useful in the methods of the invention may be administered systemically in oral solid formulations, ophthalmic, suppository, aerosol, topical or other similar formulations. For example, it may be in the physical form of a powder, tablet, capsule, lozenge, gel, solution, suspension, syrup, or the like. In addition to the iminosugar, such pharmaceutical compositions may contain pharmaceutically-acceptable carriers and other ingredients known to enhance and facilitate drug administration. Other possible formulations, such as nanoparticles, liposomes, resealed erythrocytes, and immunologically based systems may also be used to administer the iminosugar. Such pharmaceutical compositions may be administered by a number of routes. The term "parenteral" used herein includes subcutaneous, intravenous, intraarterial, intrathecal, and injection and infusion techniques, without limitation. By way of example, the pharmaceutical compositions may be administered orally, topically, parenterally, systemically, or by a pulmonary route.

These compositions may be administered in a single dose or in multiple doses which are administered at different times. Because the inhibitory effect of the composition upon a filovirus may persist, the dosing regimen may be adjusted such that virus propagation is retarded while the host cell is minimally effected. By way of example, an animal may be administered a dose of the composition of the invention once per week, whereby virus propagation is retarded for the entire week, while host cell functions are inhibited only for a short period once per week.

Embodiments described herein are further illustrated by, though in no way limited to, the following working examples.

Working Examples

1. Synthesis of N-Nonyl DNJ

Table 1. Materials for NN-DNJ synthesis

Name	Amount
DNJ	500 mg
Nonanal	530 mg
Ethanol	100 mL
AcOH	0.5 mL
Pd/C	500 mg

Procedure: A 50-mL, one-necked, round-bottom flask equipped with a magnetic stirrer was charged with DNJ (500 mg), ethanol (100 mL), nonanal (530 mg), and acetic acid (0.5 mL) at room temperature. The reaction mixture was heated to 40-45 °C and stirred for 30-40 minutes under nitrogen. The reaction mixture was cooled to ambient temperature and Pd/C was added. The reaction flask was evacuated and replaced by hydrogen gas in a balloon. This process was repeated three times. Finally, the reaction mixture was stirred at ambient temperature overnight. The progress of reaction was monitored by TLC (Note 1). The reaction mixture was filtered through a pad of Celite and washed with ethanol. The filtrate was concentrated *in vacuo* to get the crude product. The crude product was purified by column chromatography (230-400 mesh silica gel). A solvent gradient of methanol in dichloromethane (10-25%) was used to elute the product from the column. All fractions containing the desired product were combined, and concentrated *in vacuo* to give the pure product (420mg). Completion of the reaction was monitored by thin layer chromatography (TLC) using a thin layer silica gel plate; eluent; methanol : dichloromethane = 1:2

2. Synthesis of N-7-Oxadecyl DNJ

2a. Synthesis of 6-propyloxy-1-hexanol

Table 2. Materials for synthesis of 6-propyloxy-1-hexanol

Name	Amount
1,6-hexanediol	6.00 g
1-Iodopropane	8.63 g
Potassium tert-butoxide	5.413 mg
THF	140 mL

Procedure: a 500-mL, one-necked, round-bottom flask equipped with a magnetic stirrer was charged with 1,6-hexanediol (6.00 g), potassium tert-butoxide (5.413 g) at room temperature. The reaction mixture was stirred for one hour, and then 1-iodopropane (8.63 g) was added. The reaction mixture was heated to 70-80 °C and stirred overnight. The progress of reaction was monitored by TLC (Note 1). After completion of the reaction, water was added to the reaction mixture, and extracted with ethyl acetate (2 x 100 mL). The combined organic layers were concentrated *in vacuo* to get the crude product. The crude product was dissolved in dichloromethane and washed with water, and then brine, dried over sodium sulfate. The organic layer was concentrated *in vacuo* to get the crude product. The crude product was purified by column chromatography using 230-400 mesh silica gel. A solvent gradient of ethyl acetate in hexanes (10-45%) was used to elute the product from the column. All fractions containing the desired pure product were combined and concentrated *in vacuo* to give pure 6-propyloxy-1-hexanol (lot D-1029-048, 1.9 g, 25%) Completion of the reaction was monitored by thin layer chromatography (TLC); (eluent: 60% ethyl acetate in hexanes).

2b. Preparation of 6-propyloxy-1-hexanal

Table 3. Materials for preparation of 6-propyloxy-1-hexanal

Name	Amount
6-Propyloxy-1-hexanol	1.00 g

PDC	4.70 g
Celite	1.00 g
NaOAc	100 mg
CH ₂ Cl ₂	10 mL

Procedure: a 50-mL, one-necked, round-bottom flask equipped with a magnetic stirrer was charged with 6-propyloxy-1-hexanol (1.0 g), PDC (4.7 g), dichloromethane (10 mL), Celite (1.0 g), and sodium acetate (100 mg). The reaction mixture was stirred at room temperature under nitrogen for 5 minutes. PDC (4.70 g) was added to the reaction mixture, and stirred overnight. The progress of reaction was monitored by TLC (Note 1). After completion of the reaction, the reaction mixture was directly loaded on the column (230-400 mesh silica gel). A solvent gradient of dichloromethane in ethyl acetate (10-20%) was used to elute the product from the column. All fractions containing the desired pure product were combined and concentrated *in vacuo* to give pure 6-propyloxy-1-hexanal (lot D-1029-050, 710 mg, 71%). Completion of the reaction was monitored by thin layer chromatography (TLC); (eluent: 60% ethyl acetate in hexanes).

2c Synthesis of N-7-Oxadecyl-DNJ

Table 4. Materials for Synthesis of N-7-Oxadecyl-DNJ

Name	Amount
DNJ	500 mg
6-Propyloxy-1-hexanal	585 mg
Pd/C	125 mg
Ethanol	15 mL
Acetic acid	mL

Procedure: a 50-mL, one-necked, round-bottom flask equipped with a magnetic stirrer was charged with DNJ (500 mg), ethanol (15 mL), 6-propyloxy-1-hexanal (585 mg), and acetic acid (0.1mL) t room temperature. The reaction mixture was heated to 40-45 °C and stirred for 30-40 minutes under nitrogen. The reaction mixture was cooled to ambient temperature and Pd/C was added. The reaction flask was evacuated and replaced by hydrogen gas in a

balloon. This process was repeated three times. Finally, the reaction mixture was stirred at ambient temperature overnight. The progress of reaction was monitored by TLC (Note 1). The reaction mixture was filtered through a pad of Celite and washed with ethanol. The filtrate was concentrated *in vacuo* to get the crude product. The crude product was purified by column chromatography (230-400 mesh silica gel). A solvent gradient of methanol in dichloromethane (10-40%) was used to elute the product from the column. All fractions containing the desired product were combined, and concentrated *in vacuo* to give the pure product. (Lot: D-1029-052 (840 mg). Completion of the reaction was monitored by thin layer chromatography (TLC); (eluent: 50% methanol in dichloromethane).

3. Synthesis of N-(9-methoxy)-nonyl DNJ

3a Preparation of 9-methoxy-1-nonanol

Table 5. Materials for preparation of 9-methoxy-1-nonanol

Name	Amount
1,9-nonanediol	10.0 g
Dimethyl sulfate	41.39 g
Sodium hydroxide	5.0g
DMSO	100 mL

Procedure: a 500-mL, one-necked, round-bottom flask equipped with a magnetic stirrer and stir bar was charged with 1,9-nonanediol (10.00 g, 62.3 mmol) in dimethyl sulfoxide (100 mL) and H₂O (100 mL). To this was added slowly a solution of sodium hydroxide (5.0 g, 125.0 mmol) in H₂O (10 mL) at room temperature. During addition of sodium hydroxide the reaction mixture generated heat and the temperature rose to ~40 °C. The mixture was stirred for one hour, and then dimethyl sulfate (16.52 g, 131 mmol) was added in four portions while maintaining the temperature of the reaction mixture at ~ 40⁰C. The reaction mixture was stirred at room temperature overnight. Progress of the reaction was monitored by TLC (Note 1). TLC monitoring indicated that the reaction was 25 % conversion. At this stage additional dimethyl sulfate (24.78g, 196.44 mmol) was added and the resulting mixture was stirred at

room temperature for an additional 24 h. After completion of the reaction, sodium hydroxide (10% solution in water) was added to the reaction mixture to adjust the pH of the solution to 11-13. The mixture was stirred at room temperature for 2 h and extracted with dichloromethane (3 x 100 mL). The combined organic layers were washed with H₂O (200 mL), brine (150 mL), dried over anhydrous sodium sulfate (20 g), filtered and concentrated *in vacuo* to obtain a crude product (14 g). The crude product was purified by column chromatography using 250-400 mesh silica gel. A solvent gradient of ethyl acetate in hexanes (10-50%) was used to elute the product from the column. All fractions containing the desired pure product were combined and concentrated *in vacuo* to give pure 9-methoxy-1-nonanol (lot D-1027-155, 2.38 g, 21.9 %). Completion of the reaction was monitored by thin layer chromatography (TLC) using a thin layer silica gel plate; eluent: 60% ethyl acetate in hexanes.

3b Preparation of 9-methoxy-1-nonanal

Table 6. Materials for preparation of 9-methoxy-1-nonanal

Name	Amount
9-methoxy-1-nonanol	1.0 g
PDC	4.7 g
Molecular sieves, 3A	1.0 g
NaOAc	0.1 g
CH ₂ Cl ₂	10 mL

Procedure: a 50-mL, one-necked, round-bottom flask equipped with a magnetic stirrer and stir bar was charged with 9-methoxy-nonanol (1.0 g, 5.9 mmol), dichloromethane (10 mL), molecular sieves (1.0 g, 3A), sodium acetate (0.1 g) at room temperature. The reaction mixture was stirred at room temperature under nitrogen for 5 minutes. The reaction mixture was charged with pyridinium dichromate (4.7 g, 12.5 mmol) and stirred overnight. The progress of reaction was monitored by TLC (Note 1). After completion of the reaction, the reaction mixture was filtered through a bed of silica gel (~15 g). The filtrate was evaporated *in vacuo* to obtain a crude compound. This was purified by column chromatography using silica gel column (250-400 mesh, 40 g). A solvent gradient of ethyl acetate in hexane (10-

50%) was used to elute the product from the column. All fractions containing the desired pure product were combined and concentrated *in vacuo* to give pure 9-methoxy-nonanal (lot D-1027-156, 553 mg, 54.4%). Completion of the reaction was monitored by thin layer chromatography (TLC) using a thin layer silica gel plate; eluent: 60% ethyl acetate in hexanes.

3c Synthesis of N-(9-methoxy)-nonyl DNJ

Table 7. Materials for synthesis of N-(9-methoxy)-nonyl DNJ

Name	Amount
DNJ	300 mg
9-methoxy-1-nonanal	476 mg
Pd/C	200 mg
Ethanol	20 mL

Procedure: a 50-mL, two-necked, round-bottom flask equipped with magnetic stirrer and a stir bar was charged with DNJ (300 mg, 1.84 mmol), ethanol (20 mL), 9-methoxy-1-nonanal (476 mg, 2.76 mmol) at room temperature. The reaction mixture was stirred for 5-10 minutes under nitrogen and Pd/C was added at room temperature. The reaction mixture was evacuated and was replaced by hydrogen gas using a balloon. This process was repeated three times and then reaction mixture was stirred under atmospheric hydrogen at room temperature. The progress of reaction was monitored by TLC (Note 1). The reaction mixture was filtered through a bed of Celite and was washed with ethanol (20 mL). The filtrate was concentrated *in vacuo* to get a crude product. The crude product was purified by column chromatography using 250-400 mesh silica gel (20 g). A solvent gradient of methanol in ethyl acetate (5-25%) was used to elute the product from the column. All fractions containing the desired pure product were combined, and concentrated *in vacuo* to give an off white solid. The solid was triturated in ethyl acetate (20 mL), filtered and dried in high vacuum to give a white solid [lot: D-1027-158 (165.3 mg, 28.1%). Completion of the reaction was monitored by thin layer chromatography (TLC) using a thin layer silica gel plate; eluent: 50% methanol in dichloromethane.

4. Inhibition of Ebola (Zaire) and Marburg viruses

Table 1 presents IC₅₀ values for Ebola Zaire and Marburg viruses in μM . The table provides data for inhibition of infectivity of Ebola Zaire and Marburg viruses for NB-DNJ (UV-1), NN-DNJ (UV-2), N7-O-DNJ (UV-3), N9-DNJ (UV-4) and NAP-DNJ (UV-5).

Compound	Ebola Zaire Virus	Marburg Ci67
NB-DNJ	32	Not available
NN-DNJ	12	Not available
N7-O-DNJ	20	50
N9-DNJ	16	32
NAP-DNJ	6	6

Procedure. The compounds were screened for inhibition of generation of infectious virus was conducted on the UV compounds at concentrations from 6 μM up to 250 μM . The filovirus Ebola-Zaire and Marburg-Ci67 strains were evaluated for virus inhibition. Vero cells (African green monkey kidney epithelial cell line) obtained from American Type Culture Collection (ATCC, Manassas, Virginia). Cells were cultured in lx modified Eagle medium (MEM, Gibco), supplemented with 2% fetal bovine serum, 2 mM L-glutamine, 100 U/ml penicillin, 100 $\mu\text{g/ml}$ streptomycin in cell culture treated 24-well flat bottom plates at 37°C in a 5% CO₂ incubator for 24 hr prior to assay. Cells (1×10^6 cells per well) were pretreated with compounds in a final concentration of 1% DMSO for 1 hr followed by discarding the culture medium and addition of virus inoculums at an MOI of 0.1 in EMEM with 2% FBS. After 1 hr incubation the virus inoculums were removed and fresh media with compounds at correct dilutions were added. Three days later virus containing supernatants were collected and 10 fold dilutions of virus-containing supernatants was done in a virus plaque assay with Vero cells plated on 6 well- virus plaque assay plates. The plaque assay data were collected on day 8 for the Ebola and Marburg plates. IC₅₀ was determined as concentration of compound resulting in 50% virus inhibition.

Figure 5 provides data for inhibition of infectivity of Ebola Zaire and Marburg viruses for N9-DNJ (UV-4) and NAP-DNJ (UV-5).

Procedure. The virus yield assay were performed by standard plaque assay on supernatant samples generated from virus-infected cells incubated with iminosugars at concentrations

from 4 μ M up to 64 μ M. The filovirus Ebola-Zaire and Marburg-Ci67 strains were evaluated for virus inhibition. 24-well cell culture plates were seeded with Vero cells (ATCC, Mannassas, VA; ATCC number CCL-81) in 1mL lx modified Eagle medium (MEM, Gibco), supplemented with 10% heat-inactivated fetal bovine serum, 2 mM L-glutamine, 100 U/ml penicillin, 100 μ g/ml streptomycin and incubated at 37°C for 24 hours or until ~80% confluency. Medium were replaced with medium supplemented with 2% fetal bovine serum and the cells were pretreated with compounds in a final concentration of 1% DMSO for 1hr followed by discarding the culture medium and addition of virus inoculums at an MOI of 0.1 in triplicate and incubated for 1hr at 37°C, 5% CO₂. After 1 hr incubation the virus inoculums were removed and fresh media with compounds at correct dilutions were added. Three days are required for the EBOV and MARV virus infection. Upon completion of infection, supernatant were collected for titering. To titer, 6-well plates with 80% confluent Vero cells in growth medium were used. Viral supernatant were diluted from 10⁻³ to 10⁻⁸ and added (100 uL) to the cells and incubated at 37°C for 1 hour with shaking every 5-10 minutes. Viral infection medium (100 uL) were aspirated and replace with 1 mL pre-warmed 2% low-melt agarose mixed 1:1 with 2X MEM (5% fetal calf serum) and incubated at 37°C, 5% CO₂ for 8 days followed by plaque visualization by neutral red staining.

Ebola In Vivo Study

UV-5 was administered as a free drug dissolved in water. The compound was given at 100mg/kg and 10mg/kg by the intraparenteral route (IP) twice daily. Balb/c mice received the compound for 10 days. Mice were infected with Ebola virus (strain Zaire) with ~5 LD₅₀ 30 minutes following the first iminosugar dose. Animals were monitored for 15 days. Animals were weighed once per day, and given health scores 2X per day. Animals displaying severe illness (as determined by 30% weight loss, extreme lethargy, ruffled coat, or paralysis) were euthanized.

Figure 6 presents data for the effects of 10 day administration of UV-5 on survival of mice infected with Ebola virus. Animals receiving 100 mg/kg and 10 mg/kg BID showed a 71% survival rate, versus no survival in control animals.

Conclusion: these results demonstrate that UV-5 can be used as an antiviral drug to treat Ebola.

Iminosugar Safety Study

Methods and Discussion: BALB/c and C57/Bl/6 mice were given oral suspensions of UV-1, UV-4, UV-5, twice a day for seven days, in 100ul per mouse at 100 and 10 mg/kg (2mg and 0.2 mg/mouse, respectively) 8 hours apart for 7 days, and then monitored for weight loss and general health. After seven days of treatment, the mice did not show any significant signs of weight loss compared to the “vehicle only” control. The results of these experiments are in Figure 7.

When the BALB/c mice were treated with UV-5 at the highest concentration, they displayed signs of diarrhea, red urine, and a ruffled appearance although they did not show signs of weight loss. The C57/Bl/6 mice displayed these same symptoms but without the ruffled look. These symptoms promptly ceased when treatment was done, and by day 11 (day 4 post compound treatment) the BALB/c mice in these groups looked very healthy.

Conclusions: These compounds have shown to be relatively non-toxic in this mouse model and these concentrations of compound are deemed safe.

Filoviridae In Vivo Data

The study assessed the efficacy of the iminosugar compound UV-5 in promoting survival of mice challenged with Ebola and Marburg viruses. C57Bl/6 mice were used in the Ebola experiments, while Balb/c mice were used in the Marburg virus experiments. UV-5 compound was previously tested in both in vitro (CC50 of 125-250uM) and in vivo (no weight loss or adverse effects observed in multiple mouse studies) and shown it possesses low toxicity. In this study, UV-5 compound was administered to the mice as a free drug dissolved in PBS. The compound was be given by the intraperitoneal (IP) route (2x per day IP) for a total number of 10 days after the start of the compound dosing. Study mice were infected IP with Ebola Zaire or Marburg Ravn with 1000 pfu/mouse 1h before the first UV-5 dose.

Animals were monitored for 15 days. Animals were weighed once per day, and given health scores 2X per day. Animals displaying severe illness (as determined by 30% weight loss, extreme lethargy, ruffled coat, or paralysis) were euthanized.

Figure 8 shows survival data (Y-axis, percent of mice in a study group survived, X-axis, the number of days post infection) for mice infected with Ebola Zaire or Marburg Ravn viruses. Each of the groups in the study, i.e. i) a control group (treated with water only) infected with the Ebola virus, ii) a control group (treated with water only) infected with the Marburg virus; iii) a treated group (treated with 100 mg/kg of UV 5, BID) infected with the Ebola virus; iv) a treated group (treated with 10 mg/kg of UV 5, BID) infected with the Marburg virus, contained 10 mice at the beginning of the study.

Survival of $\geq 60\%$ is statistically significant. UV-5 provided significant protection against Ebola virus at dosing of 100 mg/kg IP, BID. UV-5 provided protection against Marburg virus at dosing of 10 mg/kg IP, BID.

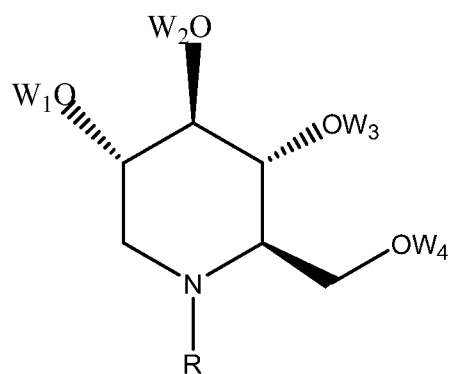
* * *

Although the foregoing refers to particular preferred embodiments, it will be understood that the present invention is not so limited. It will occur to those of ordinary skill in the art that various modifications may be made to the disclosed embodiments and that such modifications are intended to be within the scope of the present invention.

All of the publications, patent applications and patents cited in this specification are incorporated herein by reference in their entirety.

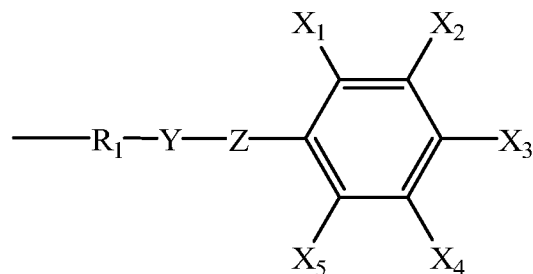
WHAT IS CLAIMED IS:

1. A method of treating or preventing a disease or condition caused by or associated with a virus belonging to the Filoviridae family, the method comprising administering to a subject in need thereof an effective amount of a compound of the formula,



, or a pharmaceutically acceptable salt thereof,

wherein R is either selected from substituted or unsubstituted alkyl groups, substituted or unsubstituted cycloalkyl groups, substituted or unsubstituted aryl groups, or substituted or unsubstituted oxaalkyl groups; or wherein R is



R₁ is a substituted or unsubstituted alkyl group;

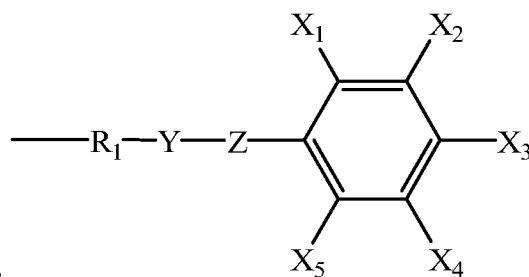
X₁₋₅ are independently selected from H, NO₂, N₃, or NH₂;

Y is absent or is a substituted or unsubstituted C₁-alkyl group, other than carbonyl; and

Z is selected from a bond or NH; provided that when Z is a bond, Y is absent, and provided that when Z is NH, Y is a substituted or unsubstituted C₁-alkyl group, other than carbonyl; and

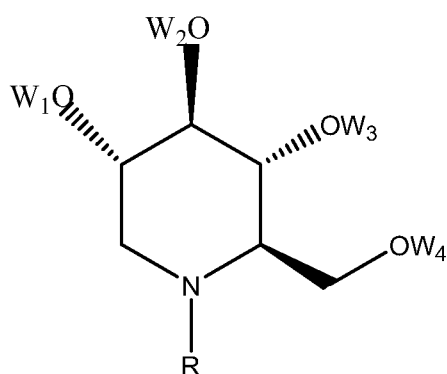
wherein W₁₋₄ are independently selected from hydrogen, substituted or unsubstituted alkyl groups, substituted or unsubstituted haloalkyl groups, substituted or unsubstituted alkanoyl groups, substituted or unsubstituted aroyl groups, or substituted or unsubstituted haloalkanoyl groups.

2. The method of claim 1, wherein each of W_1 , W_2 , W_3 and W_4 is hydrogen.
3. The method of claim 1, wherein R is selected from substituted or unsubstituted alkyl groups, substituted or unsubstituted cycloalkyl groups, substituted or unsubstituted aryl groups, or substituted or unsubstituted oxaalkyl groups.
4. The method of claim 1, wherein R is C2-C12 alkyl group.
5. The method of claim 1, wherein said administering comprises administering B-butyl deoxynojirimycin or a pharmaceutically acceptable salt thereof.
6. The method of claim 1, wherein said administering comprises administering B-nonyl deoxynojirimycin or a pharmaceutically acceptable salt thereof.
7. The method of claim 1, wherein R is an oxaalkyl group.
8. The method of claim 1, wherein R is C2-C16 oxaalkyl group that contains from 1 to 3 oxygen atoms.
9. The method of claim 1, wherein R is C6-C12 oxaalkyl group that contains from 1 to 2 oxygen atoms.
10. The method of claim 1, wherein said administering comprises administering N-(7-oxadecyl)deoxynojirimycin or a pharmaceutically acceptable salt thereof.
11. The method of claim 1, wherein said administering comprises administering is N-(9-Methoxynonyl)deoxynojirimycin or a pharmaceutically acceptable salt thereof.



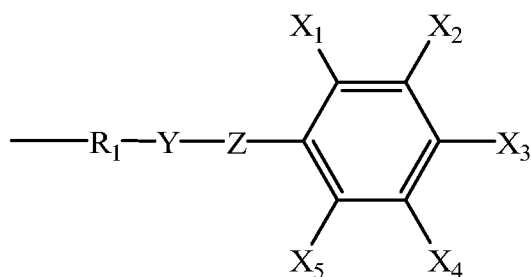
12. The method of claim 1, wherein R is
13. The method of claim 12, wherein X_1 is NO_2 and X_3 is N_3 .

14. The method of claim 12, wherein each of X₂, X₄ and X₅ is hydrogen.
15. The method of claim 12, wherein said administering comprises administering is *N*-(*N*-{4'-azido-2'-nitrophenyl}-6-aminohexyl)deoxynojirimycin or a pharmaceutically acceptable salt thereof.
16. The method of claim 12, wherein the virus is a Marburg virus.
17. The method of claim 12, wherein the virus belongs to the Ebola virus family.
18. The method of claim 17, wherein the virus is a Zaire virus.
19. The method of claim 1, wherein the subject is a mammal.
20. The method of claim 1, wherein the subject is a human being.
21. The method of claim 1, wherein the virus belongs to the Ebola virus family.
22. The method of claim 21, wherein the virus is a Zaire virus.
23. A method of inhibiting infectivity of a cell infected with a virus belonging to the Filoviridae family, the method comprising contacting a cell infected with a virus belonging to the Filoviridae family with an effective amount of a compound of the formula,



, or a pharmaceutically acceptable salt thereof,

wherein R is either selected from substituted or unsubstituted alkyl groups, substituted or unsubstituted cycloalkyl groups, substituted or unsubstituted aryl groups, or substituted or unsubstituted oxaalkyl groups; or wherein R is



R_1 is a substituted or unsubstituted alkyl group;

X_{1-5} are independently selected from H, NO_2 , N_3 , or NH_2 ;

Y is absent or is a substituted or unsubstituted C_1 -alkyl group, other than carbonyl; and

Z is selected from a bond or NH; provided that when Z is a bond, Y is absent, and provided that when Z is NH, Y is a substituted or unsubstituted C_1 -alkyl group, other than carbonyl; and

wherein W_{1-4} are independently selected from hydrogen, substituted or unsubstituted alkyl groups, substituted or unsubstituted haloalkyl groups, substituted or unsubstituted alkanoyl groups, substituted or unsubstituted aroyl groups, or substituted or unsubstituted haloalkanoyl groups, wherein said contacting reduces the infectivity of the cell.

FIGURES 1(A)-(E)

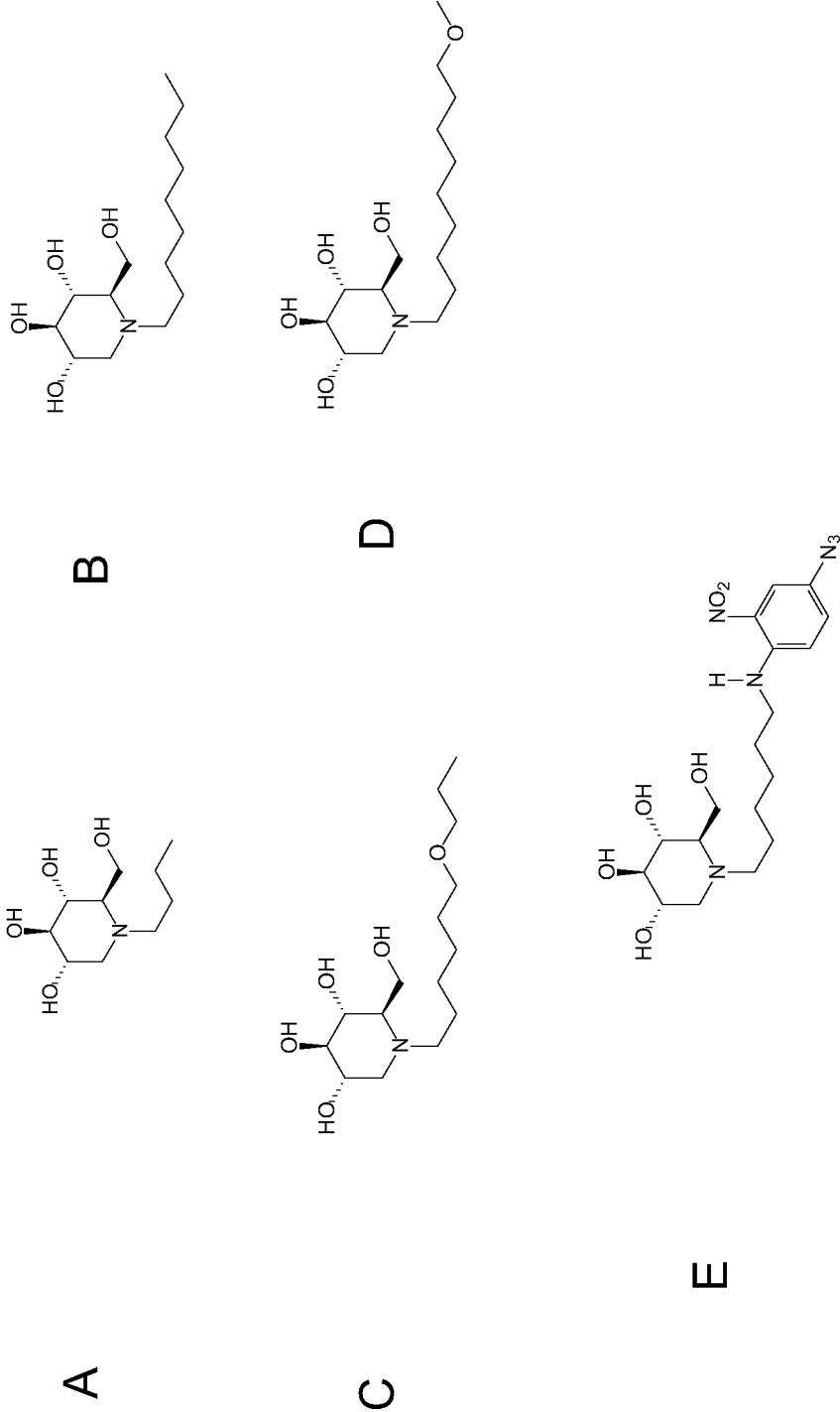


FIGURE 2

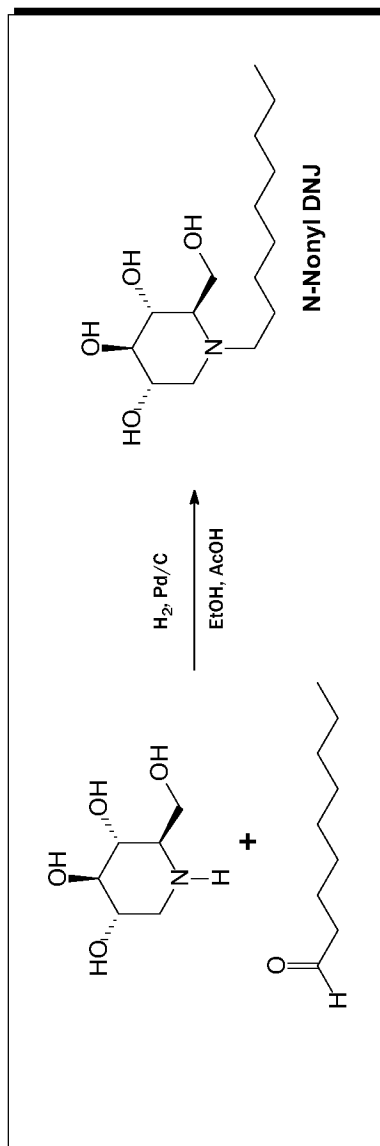
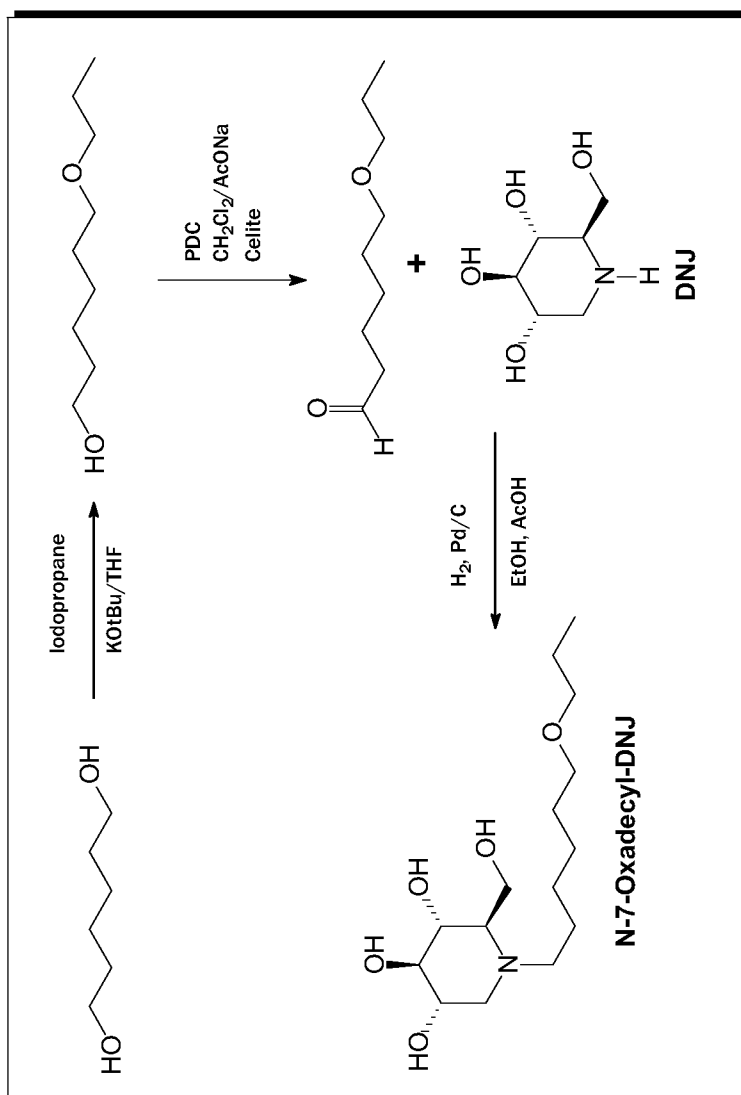
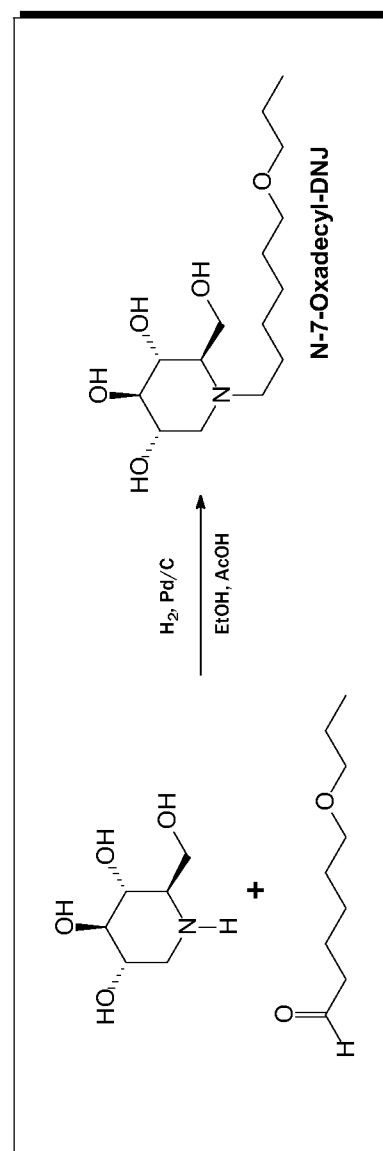
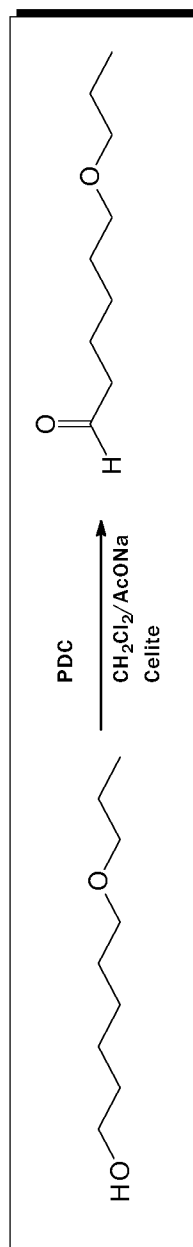
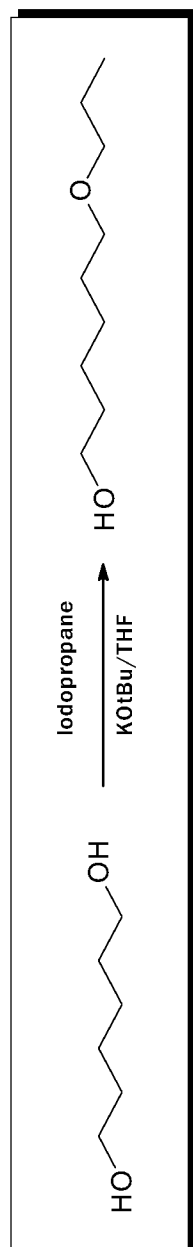


FIGURE 3A



A

FIGURES 3B-D



FIGURES 4A-C

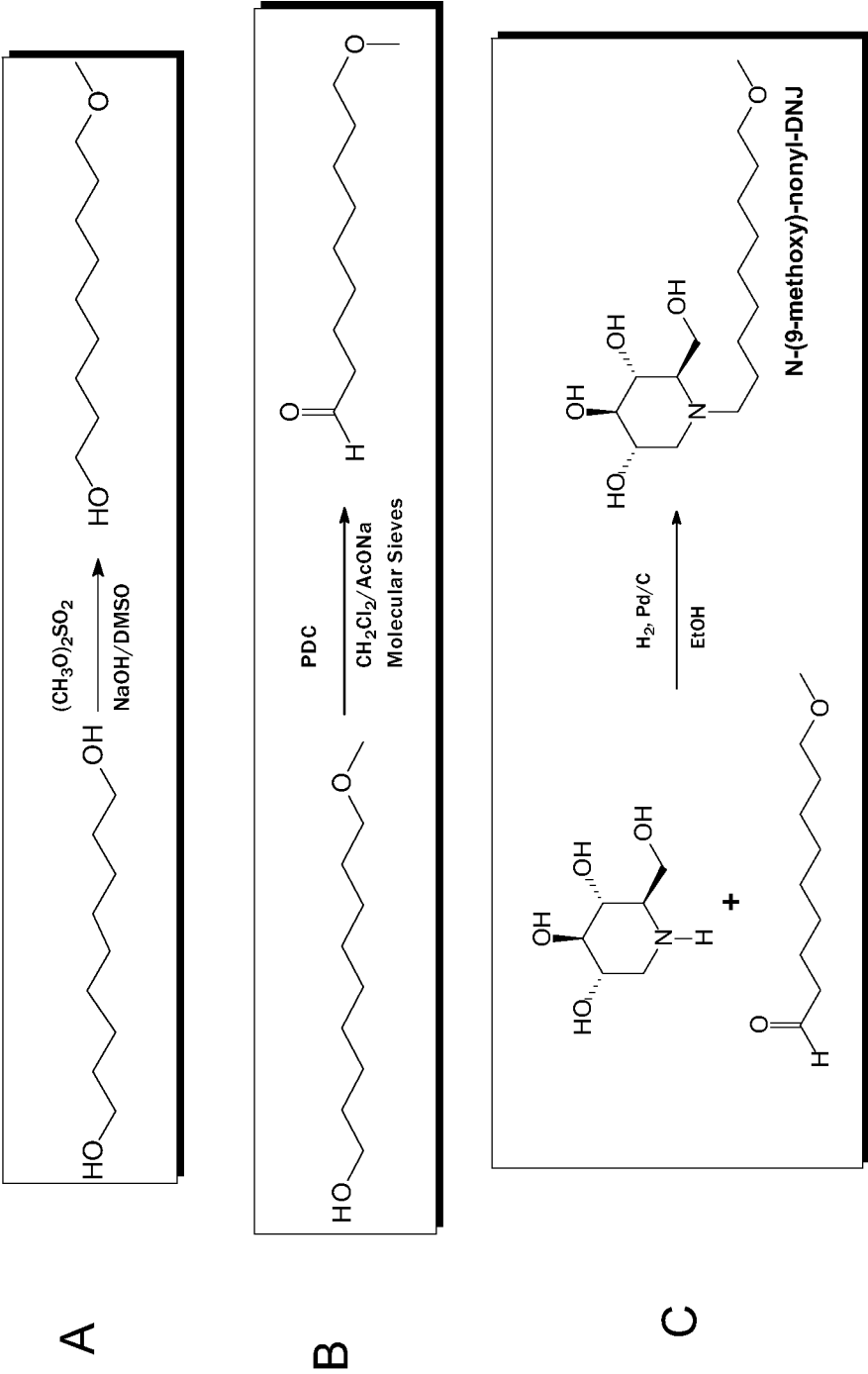
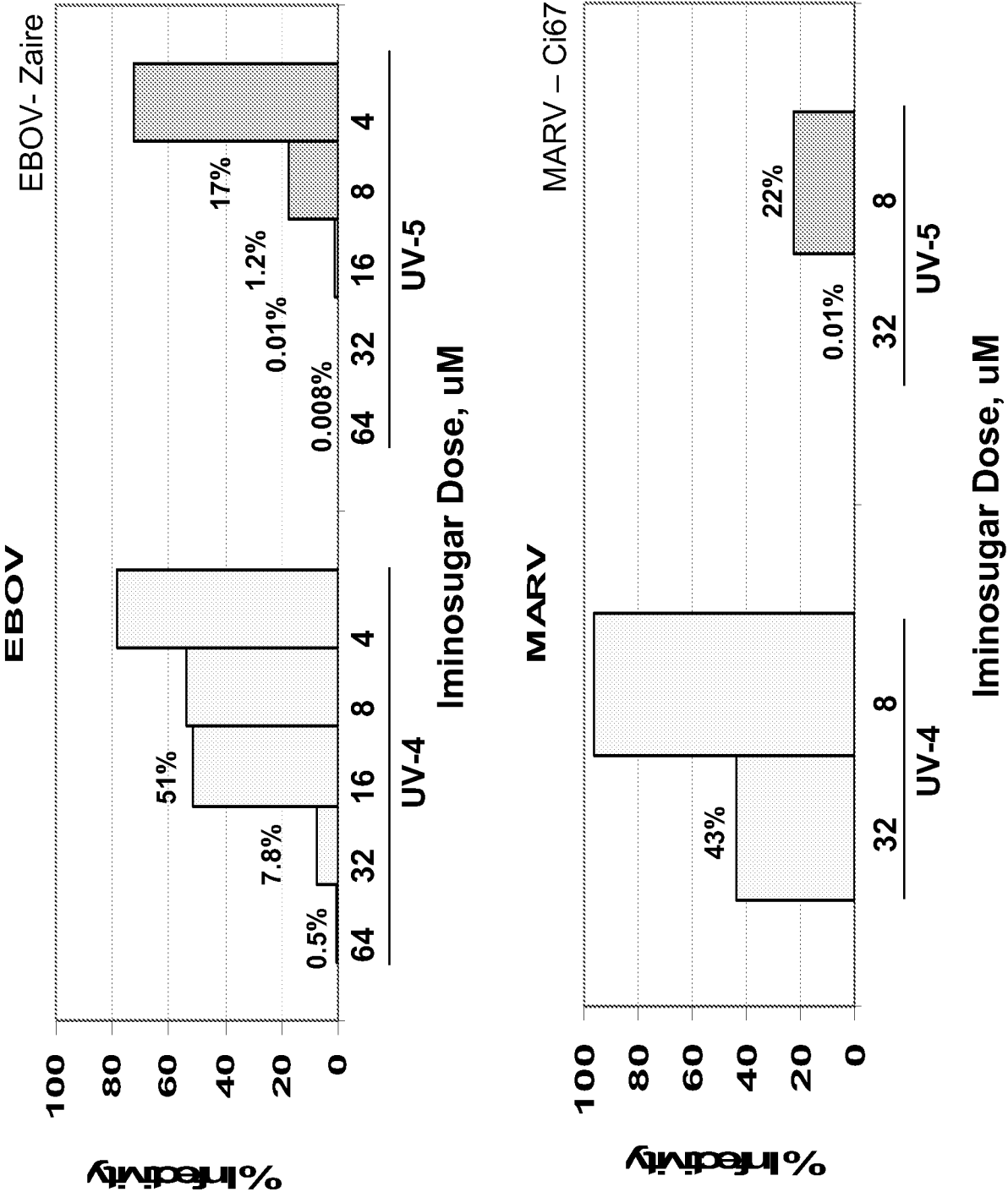


FIGURE 5



• Abbreviations: EBOV – Ebola virus; MARV – Marburg virus

FIGURE 6

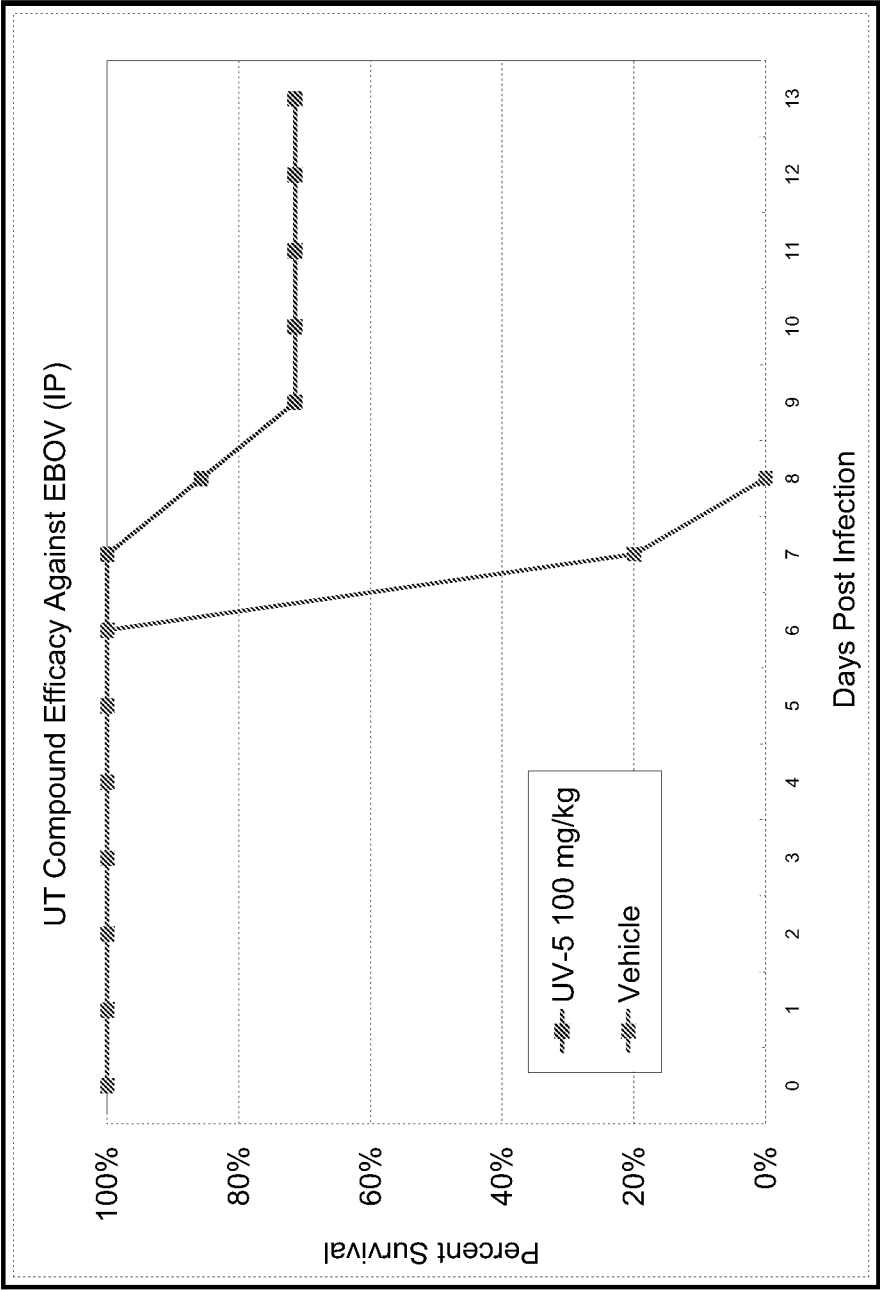
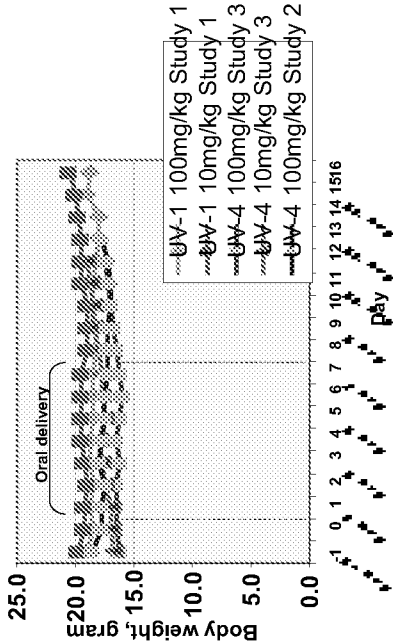


FIGURE 7

UV-4

Safety: UV-1 and UV-4 orally BID for 7 days



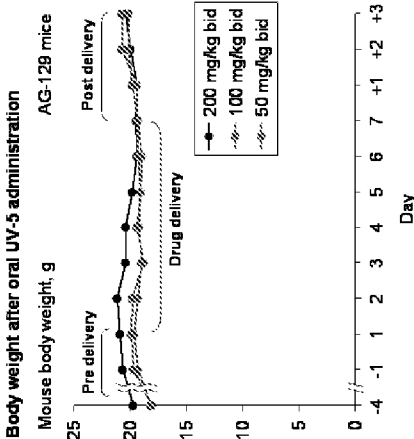
Methods

Compound administered orally for 7 days

Results

No significant weight loss
No adverse events

UV-5



Methods

Compound administered orally for 7 days

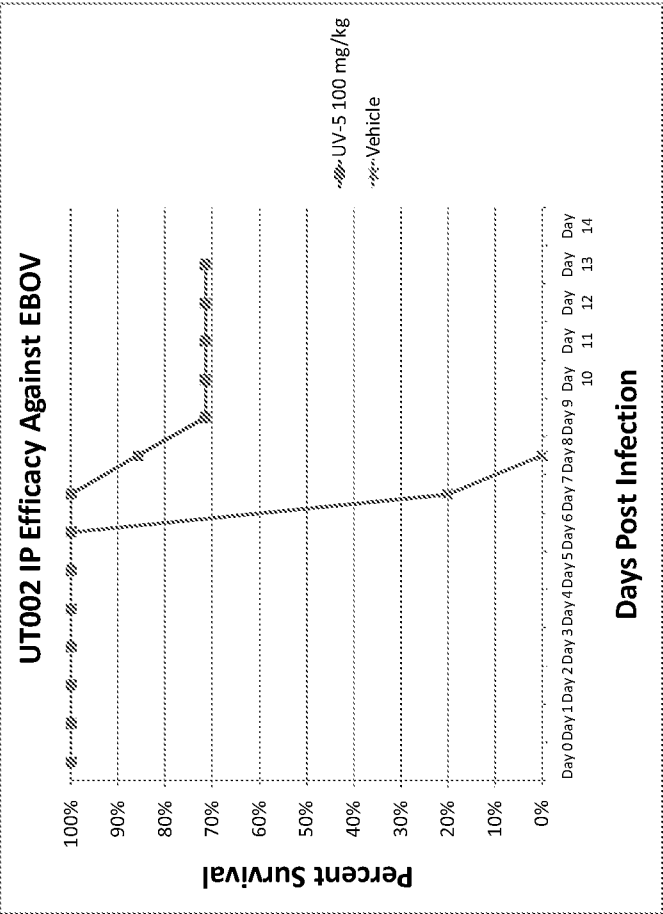
Results

No significant weight loss
No adverse events

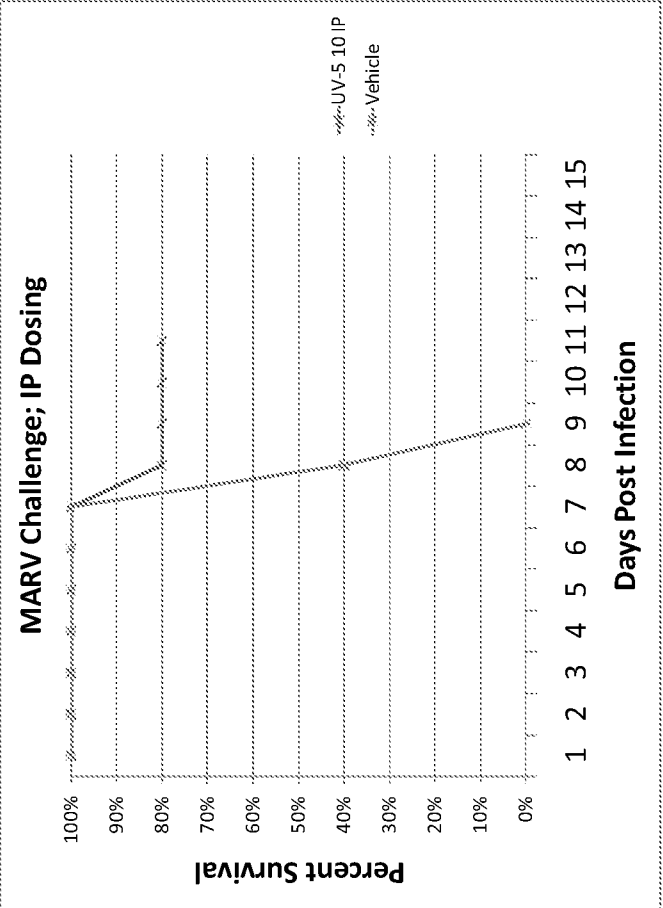
UV compounds are safe *in vivo*

Figure 8

Ebola



Marburg



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 10/47493

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A01N 43/40; A61K 31/445 (2010.01)

USPC - 514/327

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC: 514/327

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 514/151, 176, 315, 317, 319, 326; 546/216 (see search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Electronic Database Searched: PubWest (PGPB,USPT,USOC,EPAB,JPAB), Google. Search Terms Used iminosugar\$, zaire, marburg, deoxynojirimycin, treat\$, disease, filoviral, filoviridae, filoviral disease\$

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0264467 A1 (Mugrage et al.) 23 November 2006 (23.11.2006) entire document especially claim 28; para [0018], [0041], [0120], [0126], [0129], [0178]-[0179]	1-23
Y	US 2009/0186847 A1 (Stein et al.) 23 July 2009 (23.07.2009) entire document especially abstract; para [0041], [0099], [0171], [0186]	1-23
A	US 4,182,767 A (Murai et al.) 8 January 1980 (08.01.1980) entire document	1-15 and 23
A	US 2006/0074107 A1 (Butters et al.) 6 April 2006 (06.04.2006) entire document	1-15 and 23

☐

Further documents are listed in the continuation of Box C.

☐

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

9 October 2010 (9.10.2010)

Date of mailing of the international search report

15 OCT 2010

Name and mailing address of the ISA/US

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