

Description**BACKGROUND**

5 **[0001]** Liposomes are well established nanoparticles that can enhance the efficacy of therapeutically active drugs by improving the plasma distribution and pharmacokinetics of the drugs over non-encapsulated forms (e.g., Weinstein, Liposomes: From Biophysics to Therapeutics, (Ostro, M. J., ed.), Marcel Dekker, Inc., N.Y., pp. 277-338, (1987). For example, Vincristine Sulfate Liposome Injection (VSLI) is a liposome formulation of the anti-cancer therapeutic vincristine sulfate encapsulated in sphingomyelin-cholesterol liposomes which provides greater efficacy than standard vincristine sulfate injection USP (VSI). Clinical trials have also shown that VSLI facilitates dose intensification by significantly extending vincristine's circulation half-life compared to non-encapsulated vincristine. The liposome provides the mechanism for delayed drug release and the liposome size allow the drug to accumulate in cancer tissues by extravasation (Webb et al., Cancer Chemother. Pharmacol 42:461-470, 1998; Shan et al., Cancer Chemother. Pharmacol 158:245-255, 2006). These features translate into improved clinical benefit over the standard VSI.

10 **[0002]** WO0059473 [A] (Inex Pharmaceuticals Corp [CA], et al) describes improved methods for efficiently constituting liposome encapsulated vincristine for intravenous injection (VSLI) with reduced risk of operational errors and contamination. A first solution comprising vincristine sulfate is constituted along with a second solution comprising sphingomyelin/cholesterol liposomes at a low pH. The pH is raised, and then the constituting solution is heated in a water bath to produce a solution comprising constituted liposome encapsulated vincristine.

15 **[0003]** Encapsulation of vincristine sulfate into sphingomyelin-cholesterol liposomes is typically achieved by using an acidic intraliposomal pH (e.g., pH of 4) and an exterior medium at a neutral pH (e.g., pH of 7). This pH gradient allows the weakly basic vincristine to diffuse into the liposome interior with high efficiency (Cullis et al., Trends in Biotech 9: 268-272, 1991; Boman et al., Bioch Biophys Acta, 1152:253-258, 1993). In order for vincristine to accumulate in the liposome interior with the transmembrane pH gradient, the liposome membrane must become temporarily permeable to the steric bulk of vincristine. Thus, unlike neutral or anionic drugs that often can be passively encapsulated into liposomes, the temperature of the sphingomyelin-cholesterol liposome must be increased in order for the transmembrane pH gradient to function with vincristine. The liposome bilayer, which is an orientation of interlocking sphingomyelin and cholesterol molecules, requires a unique transient heat pattern to create thermotropic disorder transition states. These transition states essentially abate the weak intermolecular bonding between the membrane lipids, creating gaps in interlocking lipids and allow the liposome bilayer to become temporarily permeable. The encapsulation process takes advantage of the spontaneous self reassembly of the sphingomyelin-cholesterol lipids that occurs on cooling back to ambient temperature, which restores the membrane integrity.

20 **[0004]** This heating profile for drug encapsulation must be balanced with the chemical instability of vincristine to heat exposure (Vendrig et al., Internatl. J. of Pharmaceutics 50:189-196, 1989; Sethi et al., Cancer Res. 45:5386-5389, 1985). Vincristine is thermally labile and readily degrades to N-desformylvincristine in the presence of elevated temperatures. This formamide hydrolysis of vincristine is a well known degradation pathway and affects the stability shelf life of vincristine sulfate injection (VLSI). For example, VLSI solutions cannot be heat sterilized due to this heat lability and must be stored and shipped at refrigerated temperature to realize extended stability.

25 **[0005]** Accordingly, at the present time Vincristine Sulfate Liposome Injection (VSLI) is prepared from the individual components at a pharmacy according to the directions provided on the FDA-approved label (www.accessdata.fda.gov; Reference ID: 3172211, 2012). These directions include a heating procedure that requires the use of a water bath in order to achieve efficient encapsulation of vincristine in the sphingomyelin-cholesterol liposomes and maintain chemical purity of vincristine. The excellent heat transfer properties of water allow greater than 95% encapsulation of vincristine with no appreciable chemical degradation of the drug.

30 **[0006]** Since VSLI is an injectable drug, the manufacture of the components and pharmacy preparation are strictly regulated to maintain sterility. Accordingly, the use of an open water bath during preparation of VSLI requires additional resources, planning, and equipment (e.g., floating ring), including an aseptic hood or "clean" room in order to maintain an aseptic environment. In some pharmacies, the constitution of VSLI cannot be done due to the restrictions on maintaining a sterile environment.

35 **[0007]** Accordingly, there remains a need for improved methods of preparing VSLI that can be efficiently and reproducibly carried out without the additional resources and equipment currently required.

SUMMARY OF THE INVENTION

40 **[0008]** The current invention is based, at least in part, on the development of a method for preparing VSLI that circumvents the need for the use of a heated water bath during the encapsulation process. Thus, the invention provides efficient, reproducible methods of preparing VSLI which may be widely used with unexpected ease and reduced risk of contamination.

Results and Discussion

[0096] One constituted kit each was placed in an equilibrated heat block at 75°C for 13, 14 and 15 minutes respectively. All the sample times produced encapsulated vincristine, and there were no significant differences in test results noted between the three vials. Greater than 97% vincristine encapsulation was observed with all three vials using the Dri-Block resulting in an encapsulation efficiency with a maximum 2.3% free vincristine. No new or increased impurities were observed with the Dri-Block heating profile. The principal degradant, N-desformylvincristine, was observed at a maximum of 1.51% with no other impurity greater than 0.59% and total impurities of no more than 3.3%. The particle size distribution was consistent with VSLI specifications with an average diameter of 107 nm diameter and mean D_{25} of 90 nm and D_{90} of 137 nm.

[0097] In conclusion, VSLI constituted with the substitution of the water bath with a Dri-Block equilibrated at $75 \pm 2^\circ \text{C}$ with an incubation period of 13 to 15 minutes (± 15 seconds) encapsulated vincristine efficiently and no anomalies were recorded during the conduct of the experiment. The data establishes a Dri-Block constitution temperature profile that leads to efficient VSLI constitution and shows that the Dri-block heater can be substituted for a water bath in the constitution of the VSLI.

[0098] It is understood that the examples and embodiments described herein are for illustrative purposes only.

Claims

1. A method of preparing a pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine which is free of substantial degradation products, the method comprising:

(a) constituting in a single vial

(i) a first solution comprising vincristine sulfate at a concentration of 1 mg/ml to 5 mg/ml, wherein the first solution has a pH of 3.5 to 5.5; and

(ii) a second solution comprising sphingomyelin/cholesterol liposomes at a low pH;

(b) raising the pH of the constituting solution in the single vial to a pH of 7.0 to 7.5;

(c) heating the single vial comprising the constituting solution in a dry heat block equilibrated at 75°C for at least 13 to 18 minutes, wherein said heat block comprises one or more bores 1-5% larger than the average length or diameter of the single vial to produce a solution comprising constituted liposome encapsulated vincristine; and

(d) equilibrating the constituted solution to room temperature.

2. The method of claim 1, wherein the pH of the second solution comprising the liposomes is 4.0.

3. The method of claim 2, wherein the second solution further comprises a citrate buffer.

4. The method of claim 1, wherein the pH of the constituting solution is raised by the addition of a third solution comprising a buffer at a pH of 9.0.

5. The method of claim 4, wherein the third solution comprises sodium phosphate buffer.

6. The method of claim 1, wherein the constituting solution comprises a concentration of 0.1/1.0 to 0.2/2.0 weight vincristine sulfate to weight lipid.

7. The method of claim 6, wherein the concentration of vincristine sulfate in the constituted solution is 0.1 mg/mL to 0.5 mg/mL.

8. The method of claim 7, wherein the concentration of vincristine sulfate in the constituted solution is at 0.15 mg/mL to 0.2 mg/mL.

9. The method of claim 4, wherein the first solution comprises vincristine sulfate USP (5 mg/5 mL), which is equivalent to 4.5 mg/5 mL vincristine free base, and 500 mg/5 mL mannitol, the second solution comprises sphingomyelin/cholesterol liposomes consisting of 73.5 mg/mL sphingomyelin, 29.5 mg/mL cholesterol, 33.6 mg/mL citric acid, 35.4 mg/mL sodium citrate, and the third solution comprises 355 mg/25 mL dibasic sodium phosphate and 225 mg/25 mL sodium chloride.

10. The method of claim 1, wherein the liposomes have a size range of 0.05-0.5 microns.

Patentansprüche

5

1. Verfahren zum Herstellen einer pharmazeutisch akzeptablen flüssigen Zusammensetzung, umfassend in Liposomen verkapseltes Vincristin, das frei von wesentlichen Abbauprodukten ist, wobei das Verfahren umfasst:

10

(a) Konstituieren in einem einzelnen Fläschchen

- (i) einer ersten Lösung, umfassend Vincristinsulfat in einer Konzentration von 1 mg/ml bis 5 mg/ml, wobei die erste Lösung einen pH-Wert von 3,5 bis 5,5 hat; und
- (ii) einer zweiten Lösung, umfassend Sphingomyelin/Cholesterin-Liposomen mit einem niedrigen pH-Wert;

15

(b) Erhöhen des pH-Werts der konstituierenden Lösung in dem einzelnen Fläschchen auf einem pH-Wert von 7,0 bis 7,5;

20

(c) Erhitzen des einzelnen Fläschchens, das die konstituierende Lösung umfasst, in einem Trockenhitzeblock, der bei 75°C mindestens 13 bis 18 Minuten lang equilibriert wird, wobei der Hitzeblock eine oder mehrere Bohrungen umfasst, die 1-5% größer sind als die durchschnittliche Länge oder der durchschnittlichen Durchmesser des einzelnen Fläschchens, um eine Lösung herzustellen, die konstituiertes in Liposomen verkapseltes Vincristin umfasst; und

(d) Equilibrieren der konstituierten Lösung auf Raumtemperatur.

25

2. Verfahren nach Anspruch 1, wobei der pH-Wert der zweiten Lösung, die die Liposomen umfasst, 4,0 ist.

3. Verfahren nach Anspruch 2, wobei die zweite Lösung ferner einen Zitratpuffer umfasst.

30

4. Verfahren nach Anspruch 1, wobei der pH-Wert der konstituierenden Lösung durch den Zusatz einer dritten Lösung, umfassend einen Puffer mit einem pH-Wert von 9,0, erhöht wird.

5. Verfahren nach Anspruch 4, wobei die dritte Lösung Natriumphosphatpuffer umfasst.

35

6. Verfahren nach Anspruch 1, wobei die konstituierende Lösung eine Gewichtskonzentration von 0,1/1,0 bis 0,2/2,0 Vincristinsulfat zu Lipid umfasst.

40

7. Verfahren nach Anspruch 6, wobei die Konzentration von Vincristinsulfat in der konstituierten Lösung 0,1 mg/ml bis 0,5 mg/ml beträgt.

8. Verfahren nach Anspruch 7, wobei die Konzentration von Vincristinsulfat in der konstituierten Lösung 0,15 mg/ml bis 0,2 mg/ml beträgt.

45

9. Verfahren nach Anspruch 4, wobei die erste Lösung Vincristinsulfat USP (5 mg/5 ml) umfasst, was 4,5 mg/5 ml Vincristin freier Base und 500 mg/5 ml Mannitol entspricht, die zweite Lösung Sphingomyelin/Cholesterin-Liposomen umfasst, bestehend aus 73,5 mg/ml Sphingomyelin, 29,5 mg/ml Cholesterin, 33,6 mg/ml Zitronensäure, 35,4 mg/ml Natriumzitat, und die dritte Lösung 355 mg/25 ml doppelbasisches Natriumphosphat und 225 mg/25 ml Natriumchlorid umfasst.

50

10. Verfahren nach Anspruch 1, wobei die Liposomen einen Größenbereich von 0,05-0,5 Mikron aufweisen.

Revendications

55

1. Procédé de préparation d'une composition liquide pharmaceutiquement acceptable comprenant de la vincristine encapsulée dans des liposomes et dénuée de produits de dégradation importants, le procédé comprenant :

(a) la constitution dans un flacon unique

- (i) d'une première solution comprenant du sulfate de vincristine à une concentration de 1 mg/ml à 5 mg/ml,

Description**BACKGROUND**

5 **[0001]** Liposomes are well established nanoparticles that can enhance the efficacy of therapeutically active drugs by improving the plasma distribution and pharmacokinetics of the drugs over non-encapsulated forms (e.g., Weinstein, Liposomes: From Biophysics to Therapeutics, (Ostro, M. J., ed.), Marcel Dekker, Inc., N.Y., pp. 277-338, (1987). For example, Vincristine Sulfate Liposome Injection (VSLI) is a liposome formulation of the anti-cancer therapeutic vincristine sulfate encapsulated in sphingomyelin-cholesterol liposomes which provides greater efficacy than standard vincristine sulfate injection USP (VSI). Clinical trials have also shown that VSLI facilitates dose intensification by significantly extending vincristine's circulation half-life compared to non-encapsulated vincristine. The liposome provides the mechanism for delayed drug release and the liposome size allow the drug to accumulate in cancer tissues by extravasation (Webb et al., Cancer Chemother. Pharmacol 42:461-470, 1998; Shan et al., Cancer Chemother. Pharmacol 158:245-255, 2006). These features translate into improved clinical benefit over the standard VSI.

10 **[0002]** WO0059473 [A] (Inex Pharmaceuticals Corp [CA], et al) describes improved methods for efficiently constituting liposome encapsulated vincristine for intravenous injection (VSLI) with reduced risk of operational errors and contamination. A first solution comprising vincristine sulfate is constituted along with a second solution comprising sphingomyelin/cholesterol liposomes at a low pH. The pH is raised, and then the constituting solution is heated in a water bath to produce a solution comprising constituted liposome encapsulated vincristine.

15 **[0003]** Encapsulation of vincristine sulfate into sphingomyelin-cholesterol liposomes is typically achieved by using an acidic intraliposomal pH (e.g., pH of 4) and an exterior medium at a neutral pH (e.g., pH of 7). This pH gradient allows the weakly basic vincristine to diffuse into the liposome interior with high efficiency (Cullis et al., Trends in Biotech 9: 268-272, 1991; Boman et al., Bioch Biophys Acta, 1152:253-258, 1993). In order for vincristine to accumulate in the liposome interior with the transmembrane pH gradient, the liposome membrane must become temporarily permeable to the steric bulk of vincristine. Thus, unlike neutral or anionic drugs that often can be passively encapsulated into liposomes, the temperature of the sphingomyelin-cholesterol liposome must be increased in order for the transmembrane pH gradient to function with vincristine. The liposome bilayer, which is an orientation of interlocking sphingomyelin and cholesterol molecules, requires a unique transient heat pattern to create thermotropic disorder transition states. These transition states essentially abate the weak intermolecular bonding between the membrane lipids, creating gaps in interlocking lipids and allow the liposome bilayer to become temporarily permeable. The encapsulation process takes advantage of the spontaneous self reassembly of the sphingomyelin-cholesterol lipids that occurs on cooling back to ambient temperature, which restores the membrane integrity.

20 **[0004]** This heating profile for drug encapsulation must be balanced with the chemical instability of vincristine to heat exposure (Vendrig et al., Internatl. J. of Pharmaceutics 50:189-196, 1989; Sethi et al., Cancer Res. 45:5386-5389, 1985). Vincristine is thermally labile and readily degrades to N-desformylvincristine in the presence of elevated temperatures. This formamide hydrolysis of vincristine is a well known degradation pathway and affects the stability shelf life of vincristine sulfate injection (VLSI). For example, VLSI solutions cannot be heat sterilized due to this heat lability and must be stored and shipped at refrigerated temperature to realize extended stability.

25 **[0005]** Accordingly, at the present time Vincristine Sulfate Liposome Injection (VSLI) is prepared from the individual components at a pharmacy according to the directions provided on the FDA-approved label (www.accessdata.fda.gov; Reference ID: 3172211, 2012). These directions include a heating procedure that requires the use of a water bath in order to achieve efficient encapsulation of vincristine in the sphingomyelin-cholesterol liposomes and maintain chemical purity of vincristine. The excellent heat transfer properties of water allow greater than 95% encapsulation of vincristine with no appreciable chemical degradation of the drug.

30 **[0006]** Since VSLI is an injectable drug, the manufacture of the components and pharmacy preparation are strictly regulated to maintain sterility. Accordingly, the use of an open water bath during preparation of VSLI requires additional resources, planning, and equipment (e.g., floating ring), including an aseptic hood or "clean" room in order to maintain an aseptic environment. In some pharmacies, the constitution of VSLI cannot be done due to the restrictions on maintaining a sterile environment.

35 **[0007]** Accordingly, there remains a need for improved methods of preparing VSLI that can be efficiently and reproducibly carried out without the additional resources and equipment currently required.

SUMMARY OF THE INVENTION

40 **[0008]** The current invention is based, at least in part, on the development of a method for preparing VSLI that circumvents the need for the use of a heated water bath during the encapsulation process. Thus, the invention provides efficient, reproducible methods of preparing VSLI which may be widely used with unexpected ease and reduced risk of contamination.

[0009] The invention features a method of preparing a pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine which is free of substantial degradation products, the method comprising the steps of (a) constituting in a single vial (i) a first solution comprising vincristine sulfate at a concentration of 1 mg/ml to 5 mg/ml, wherein the first solution has a pH of 3.5 to 5.5; and (ii) a second solution comprising sphingomyelin/cholesterol liposomes at a low pH; (b) raising the pH of the constituting solution in the single vial to a pH of 7.0 to 7.5; (c) heating the single vial comprising the constituting solution in a dry heat block equilibrated at 75°C for at least 13 to 18 minutes, wherein said heat block comprises one or more bores 1-5% larger than the average length or diameter of the single vial to produce a solution comprising constituted liposome encapsulated vincristine; (d) equilibrating the constituted solution to room temperature, as defined in claim 1.

[0010] Subsequent administration to the patient will involve (e) diluting a volume of the constituted solution comprising a dose of liposome encapsulated vincristine for the patient of about 1.5 to about 2.4 mg/m² with a pharmaceutical diluent suitable for intravenous administration, to produce the pharmaceutically acceptable liquid composition; and (f) administering the pharmaceutically acceptable liquid composition to the patient, wherein the constituted solution comprising liposome encapsulated vincristine comprises (i) less than about 2.5% free vincristine; and (ii) less than about 1.5% N-desformylvincristine.

[0011] In some embodiments, the first solution comprising vincristine sulfate has pH of about 4.5 to about 4.7. In one embodiment, the first solution further comprises mannitol at a concentration of about 100-200 mg/ml.

[0012] In some embodiments, the pH of the second solution comprising the liposomes is about 4.0. In one embodiment, the second solution further comprises a citrate buffer.

[0013] In some embodiments, the pH of the constituting solution is raised by the addition of a third solution comprising a buffer at a pH of about 9.0. In one embodiment, the third solution comprises sodium phosphate buffer.

[0014] In some embodiments, the constituting solution comprises a concentration ratio of about 0.1/1.0 to about 0.2/2.0 vincristine sulfate to lipid.

[0015] In some embodiments, the concentration of vincristine sulfate in the constituted solution is about 0.1 mg/mL to about 0.5 mg/mL. In some embodiments, the concentration of vincristine sulfate in the constituted solution is about at about 0.15 mg/mL to about 0.2 mg/mL. In one embodiment, the concentration of vincristine sulfate in the constituted solution is about 0.16 mg/mL.

[0016] In one embodiment, the first solution comprises vincristine sulfate USP (5 mg/5 mL), which is equivalent to 4.5 mg/5 mL vincristine free base, and 500 mg/5 mL mannitol, the second solution comprises sphingomyelin/cholesterol liposomes consisting of 73.5 mg/mL sphingomyelin, 29.5 mg/mL cholesterol, 33.6 mg/mL citric acid, 35.4 mg/mL sodium citrate, and the third solution comprises 355 mg/25 mL dibasic sodium phosphate and 225 mg/25 mL sodium chloride.

[0017] In some embodiments, the ratio of sphingomyelin to cholesterol in the liposome is between about 75/25 mol %/mol sphingomyelin/cholesterol to 30/50 mol %/mol % sphingomyelin/cholesterol. In some embodiments, the liposomes comprise about 70/30 mol %/mol sphingomyelin/cholesterol to 40/45 mol %/mol % sphingomyelin/cholesterol. In one embodiment, the liposomes comprise approximately 55/45 mol %/mol % sphingomyelin/cholesterol. In another embodiment, the liposomes comprising about 60/40 mol %/mol % sphingomyelin/cholesterol.

[0018] In some embodiments, the liposomes have a size range of about 0.05-0.5 microns. In some embodiments, the liposomes have a mean diameter of about 50-200 nm. In one embodiment, the liposomes have a mean diameter of about 90-125 nm.

[0019] In some embodiments, the constituting solution has a volume of between about 20-50 mL. In some embodiments, the constituting solution has a volume of between 30-35 mL.

[0020] In some embodiments, the heat block is equilibrated to 75±2°C for about 15 minutes prior to insertion of the vial containing the constituting solution. In some embodiments, the constituting solution is heated for about 13-15 minutes within the caliber bore of a dri-block equilibrated at 75±2°C. In one embodiment, the constituting solution is heated for 14 minutes ± 30 seconds within the caliber bore of a dri-block equilibrated at 75±2°C.

[0021] In some embodiments, the bores in the heat block are less than about 3% larger than the average length or diameter of the single vial containing the constituting solution. In some embodiments, the single vial containing the constituting solution has a diameter between about 35.8 to about 37.3 mm, and the caliber bores in the heat block are cylindrical with a diameter between 37.2 to 37.8 mm in diameter.

[0022] In some embodiments, the constituted solution is equilibrated to room temperature for at least about 30 minutes.

[0023] In some embodiments, the volume of the constituted solution comprising a dose of liposome encapsulated vincristine for the patient of about 1.5 to about 2.4 mg/m² is diluted with standard pharmaceutical diluents suitable for intravenous administration, to produce the pharmaceutically acceptable liquid composition. In some embodiments, the volume of the patients calculated dose is removed from an infusion container and replaced with the calculated volume of the constituted VSLI solution.

[0024] The pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine may be administered to the patient within no more than 24 hours after constitution.

[0025] The VSLI produced according to the methods of the invention are typically administered to a patient having

cancer. In some embodiments, the cancer is lymphoma, leukemia, myeloma, brain cancer or neuroblastoma.

[0026] The pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine may be administered by intravenous infusion over a period of about 30 to 60 minutes. The pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine may be administered by intravenous infusion once every 7-28 days. The pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine may be administered by intravenous infusion once every 7 days.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] **Figure 1** is a graph depicting the internal heating profile of a constituted solution containing vincristine sulfate and sphingomyelin/cholesterol liposomes using a dry block and water bath.

DETAILED DESCRIPTION

[0028] The present invention overcomes the deficiencies associated with the use of a water bath during the currently used methods of preparing VLSI. Surprisingly, it was discovered that the use of a heating block with a custom designed insert designed to conform to the container used for constituting the VSLI provides the heat profile needed to achieve uniform encapsulation of vincristine without significant degradation.

[0029] In addition, the improved ability of the methods of preparing VSLI described herein to demonstrate parametric release is significant. Since the stability of VSLI warrants "just in time" preparation, the constitution process must be highly efficient and reproducible by the pharmacist. The pharmacist needs to know (i.e., parametrically) that the encapsulation has been achieved by the heat induced process because it provides "a system of release that gives the assurance that a product is of the intended quality based on the review of information collected during the constitution process and on the compliance with specific GMP requirements related to parametric release" (Annex 17 EU guidance).

[0030] The heating block procedure of the present invention provides a convenient and compliant process to achieve constitution of VSLI with greater than 95% encapsulation efficiency. Since it involves fewer steps, the probability of operational errors is decreased. The process is overall more straightforward, takes less time, uses fewer resources, and is convenient for routine pharmacy operation. Additionally, the individual preparing the VSLI need not deal with potential microbial contamination from microbes growing in the water bath or water vapor from the heated water bath.

Definitions

[0031] Unless specifically noted otherwise, all technical and scientific terms used herein have the standard definitions commonly understood by one of ordinary skill in the art of therapeutic and pharmaceutical science.

[0032] The singular form "a," "an," and "the" include plural reference unless the context clearly dictates otherwise.

[0033] The terms "comprise" and "comprising" are used in the inclusive, open sense, meaning that additional elements may be included.

[0034] The term "about", particularly in reference to a given quantity or number, is meant to encompass deviations of plus or minus five percent.

[0035] A "sterile" composition or container, as used herein, is free of viable microbes as determined using the USP sterility test. (See, "The United States Pharmacopeial Convention: 2008).

[0036] "Liposome" "vesicle" and "liposome vesicle" will be understood to indicate structures having lipid-containing membranes enclosing an aqueous interior. The structures may have one or more lipid membranes unless otherwise indicated, although generally the liposomes will have only one membrane. Such single-layered liposomes are referred to herein as "unilamellar". Multilayer liposomes are referred to herein as "multilamellar".

[0037] A "standard" therapeutic agent, or "free" therapeutic agent, refers to a therapeutic agent that is not liposome-encapsulated. Usually, a drug is presumed to be "standard" or "free" unless specified otherwise. A standard vinca alkaloid in free form may still be present in combination with other reagents, however, such as other chemotherapeutic compounds, a pharmaceutical carrier, or complexing agents, i.e. as used herein the term only specifically excludes lipid formulations of the vinca alkaloids.

[0038] The phrase "just in time" refers to the combining the separate components of a drug product (e.g., VSLI) shortly (e.g., within 24 hours or less) before administration to the patient in order to maintain the quality of the drug product (e.g., minimize degradation).

[0039] "Systemic delivery," as used herein, refers to delivery that leads to a broad bio-distribution of a compound within an organism. Systemic delivery means that a useful, preferably therapeutic, amount of a compound is exposed to most parts of the body. To obtain broad bio-distribution generally requires a route of introduction such that the compound is not rapidly degraded or cleared (such as by first pass organs (liver, lung, etc.) or by rapid, nonspecific cell binding) before reaching a disease site. Systemic delivery of liposome-encapsulated vinca alkaloids is preferably obtained by intravenous

delivery.

[0040] The phrase "therapeutically effective amount" refers to an amount of drug (e.g., VSLI) effective to treat a disease or disorder (e.g., cancer) in a mammal, for example, resulting in stable disease, partial remission or complete remission of the cancerous state.

[0041] A "stable disease," as used herein, refers to a state wherein administration of the drug (e.g., VSLI) causes cessation of the growth or prevalence of a tumor or cancer as measured by standard clinical, radiological and/or biochemical means, although there is no regression or decrease in the size or prevalence of the cancer.

[0042] A "Partial response" or "partial remission" refers to the amelioration of a cancerous state, as measured by standard clinical, radiological and/or biochemical means, in response to treatment. Typically, a "partial response" means that the size of a tumor or the level of a cancer-indicating blood marker has decreased from a baseline level (e.g., 20%, 30%, 40% or 50%) in response to treatment. For example, for treatment of blood cancers the responses are assessed based on the international working group criteria (International Working Group (IWS) criteria; BD Cheson et al, J Clin Oncol 15:4642-4649).

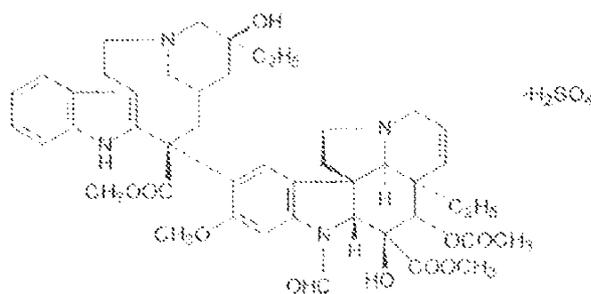
[0043] A "complete response" or "complete remission" means that a cancerous state, as measured by, for example, tumor size and/or cancer marker levels, is undetectable following treatment.

[0044] "Neurological toxicity" includes symptoms of neuropathy, such as hypoesthesia, hyperesthesia, paresthesia, hyporeflexia, areflexia, neuralgia, jaw pain, decreased vibratory sense, cranial neuropathy, ileus, burning sensation, arthralgia, myalgia, muscle spasm, weakness, and/or orthostatic hypotension both before and during treatment. Orthostatic hypotension may occur. A Neurological toxicity is assessed as being Grade 1 to Grade 3 based on the National Cancer Institute (NCI) Common Terminology Criteria for Adverse Events (CTCAE) version 4.03 (<http://ctep.cancer.gov/reporting/etc.html>).

Vincristine Sulfate

[0045] Vincristine sulfate is a member of a vinca alkaloid family originally isolated from the periwinkle plant (*Catharanthus roseus*). Vincristine Sulfate has cell-cycle specific anticancer activity. The vinca alkaloid bind to tubulin, altering tubulin polymerization leading to metaphase arrest, inhibition of cell mitosis, and cell death. As a cell cycle specific agent its' therapeutic response is advanced by liposome encapsulation which maintains extended drug levels. Prolonged exposure of cells to vincristine (and other cell cycle specific drugs) has been shown to enhance in-vitro cytotoxicity of the drug (Bfarris et al, JNCI 84; 1816-1826, 1992; Georgiadis et al., Clin Cancer Res 3:449-454, 1997; Jackson and Bender, Cancer Res 39:4346-4349, 1979).

[0046] Vincristine sulfate is commonly isolated as a 1:1 sulfate salt. It is a hygroscopic, white to slightly yellowish crystalline powder that is soluble in water. It has a molecular weight of 923.04 (salt form) / 824.98 (base form) and a molecular formula of $C_{46}H_{56}N_4O_{10} \cdot H_2SO_4$. The chemical name for vincristine sulfate is 22-oxovincalcoloblastine and it has the following chemical structure:



[0047] Vincristine sulfate is prescribed as vincristine sulfate injection USP (e.g., as a 1 mg/mL solution) and is also known as leurocristine sulfate, Kyocristine, vincosid, vincex, oncovin, Vincasar PFS®, is commercially available from any of a number of sources.

Liposomes

[0048] The liposome carrier component of the present invention are comprised of sphingomyelin and cholesterol liposomes injection (SCLI). The ratio of sphingomyelin to cholesterol present in the liposome may vary, but generally is in the range of from 75/25 mol %/mol sphingomyelin/cholesterol to 30/50 mol % mol % sphingomyelin/cholesterol. In one embodiment, the liposome composition comprise about 70/30 mol % mol sphingomyelin/cholesterol to 40/45 mol % mol % sphingomyelin/cholesterol. In another embodiment, the liposome compositions comprise approximately 55/45

mol % mol % sphingomyelin/cholesterol. In still another embodiment the liposome compositions comprise about 60/40 mol % mol % sphingomyelin/cholesterol.

[0049] In certain embodiments, additional lipids may be present in the formulations, for example, to prevent lipid oxidation or to attach ligands onto the liposome surface. Generally, the inclusion of other lipids will result in a decrease in the sphingomyelin/cholesterol ratio.

[0050] The sphingomyelin/cholesterol liposomes used in the present invention can be multilamellar or unilamellar. Suitable methods for preparing the liposomes include, but are not limited to, sonication, extrusion, high pressure/homogenization, microfluidization, detergent dialysis, calcium-induced fusion of small liposome vesicles, thin film evaporation, and ether-infusion methods, all of which are well known in the art. For example, a variety of methods are available for preparing liposomes as described in, e.g., Szoka, et al., *Ann. Rev. Biophys. Bioeng.*, 9:467 (1980), U.S. Pat. Nos. 4,186,183, 4,217,344, 4,235,871, 4,261,975, 4,485,054, 4,501,728, 4,774,085, 4,837,028, 4,946,787, 5,543,152, 6,723,338, WO 91/17424, Deamer and Bangham, *Biochim. Biophys. Acta*, 443:629 634 (1976); Fraley, et al., *Proc. Natl. Acad. Sci. USA*, 76:3348 3352 (1979); Hope, et al., *Biochim. Biophys. Acta*, 812:55 65 (1985); Mayer, et al., *Biochim. Biophys. Acta*, 858:161 168 (1986); Williams, et al., *Proc. Natl. Acad. Sci.*, 85:242 246 (1988), the text *Liposomes*, Marc J. Ostro, ed., Marcel Dekker, Inc., New York, 1983, Chapter 1, and Hope, et al., *Chem. Phys. Lip.*, 40:89 (1986).

[0051] Following liposome preparation, the liposomes can be sized to achieve the desired particle size range using standard methods well-known in the art (e.g., see US 6,723,338). Typically liposomes which can be used in the VSLI preparations described herein have a size range of about 0.05-0.5 microns (50-500 nm), 0.2-0.4 microns (200-400 nm), about 0.1-0.4 microns (100-400 nm), about 0.05-0.2 (50-200 nm) or about 0.5 (500 nm) to about 0.15 microns (150 nm). In certain embodiments, the liposomes have a particle size having a mean particle diameter of about 50 nm, about 60 nm, about 70 nm, about 80 nm, about 90 nm, about 100 nm, about 105 nm, about 110 nm, about 115 nm, about 120 nm, about 130 nm, about 140 nm, about 150 nm, about 160 nm, 170 nm, about 180 nm, about 190 nm, or about 200 nm. In one embodiment, the average particle size is between 90 and 125nm with the preferred average particle size about 107.5 nm, where 25% of the particle size distribution is not less than 70nm and where 90% of the distribution has a particle size of not more than 170 nm.

[0052] The sphingomyelin/cholesterol liposomes function as the liposome component used in the VSLI preparations described herein and are manufactured so that the liposome interior has a low pH. During the constitution process VSI, having a low pH, and SPLI, having a low pH, are diluted in a buffer of a higher pH whereby the final pH of the external VSLI solution is about physiologically neutral. The result is the creation of a pH gradient across the lipid membrane in which the pH is lower in the interior core of the liposomes than the exterior surrounding solution. Such gradients are achieved according to known methods (e.g., US 6,723,338). For example, gradients can be achieved by formulating the liposomes in the presence of a buffer with a pH between about 2 and about 6, a pH between about 3 and about 5, and then subsequently transferring the liposomes to a higher pH, for example, of about 7.0 to about 7.5. In one embodiment, the liposomes have an interior pH of about 4.0. Any number of dilution buffers can be used, such as sodium phosphate. In one embodiment the buffer has a pH of 8-10, preferably 9.0, so that the final diluted external liposome solution when mixed with VSI and SPLI will have a physiologic neutral pH.

[0053] Prior to use in the preparation of VSLI according to the methods described herein, the SPLI liposomes can be stored at refrigerated conditions for substantial periods of time prior to drug encapsulation and constitution of VSLI for administration to a patient. Alternatively, the liposomes can be dehydrated, stored and then rehydrated prior to use in accordance with well-known methods (See, e.g., US Patents 5,077,056 or 5,736,155).

VSLI Preparation

[0054] VSLI is prepared with strict aseptic techniques, for example, in a biological safety cabinet or by established pharmacy safety procedures for the preparation of sterile injectable formulations and hazardous drugs. Procedures for handling and disposal of anticancer drugs must be strictly followed (NIOSH Alert: Preventing occupational exposure to antineoplastic and other hazardous drugs in healthcare settings. 2004. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-16; OSHA Technical Manual, TED 1-0.15A, Section VI: Chapter 2. Controlling Occupational Exposure to Hazardous Drugs. OSHA, 1999; American Society of Health-System Pharmacists. ASHP guidelines on handling hazardous drugs. *Am J Health-Syst Pharm.* (2006) 63:1172-1193; Polovich M, White JM, Kelleher LO (eds.) 2005. *Chemotherapy and biotherapy guidelines and recommendations for practice* (2nd. ed.) Pittsburgh, PA: Oncology Nursing Society)

[0055] The process for preparing constituted VSLI includes the following general steps:

- A constituting solution is prepared by mixing in a sterile container a first solution of vincristine sulfate containing between about 1 mg/mL, about 2 mg/mL or about 5 mg/mL in a buffer containing about 100 to about 200 mg/mL mannitol (other pharmaceutically acceptable excipients in which vincristine sulfate remains stable can also be used)

at a pH of about 3.5 to about 5.5, or about 4.5 to about 4.7, with a second solution of liposomes suspended in a buffer at low pH (e.g., about 4.0) at an appropriate concentration ratio, for example, 0.1/1.0 to 0.2/1.0 (weight vincristine sulfate to weight lipid).

- The pH of the constituting solution containing the vincristine sulfate and liposomes is then raised to about 7.0 to about 7.5 to create a pH gradient. This can be accomplished, for example, by the addition of a buffer (e.g., sodium phosphate) at a higher pH (e.g., about 9.0).
- The constituting solution is then heated for at least about 13 to about 18 minutes in a dry heat block equilibrated to about 75°C, which contains caliber wells less than about 5%, larger than the average length or diameter of the container containing the constituting solution to produce the constituted product, VSLI.
- The heated, constituting solution comprising the constituted product is then allowed to equilibrate for at least about 30 minutes, at least about 45 minutes or at least about 60 minutes to room temperature (15°C to 30°C,).
- A volume of the constituting solution corresponding to the dose of the constituted VSLI to be administered to the patient is then admixed with a solution suitable for intravenous administration to a final volume of about 100 mL.

[0056] In some embodiments, solutions of vincristine sulfate, liposomes and high pH buffer are provided in three separate containers. In certain embodiments, the three solutions are constituted into one sterile container with a capacity to contain the combined volume of the solutions, for example, about 20-50 mL, about 25-40 mL, or about 30-35 mL.

[0057] In one embodiment, the separate components are provided as a kit including 3 or more vials. At least one of the vials contains a vincristine solution containing, e.g., 1 mg/mL, 2 mg/mL, or 5 mg/mL vincristine sulfate in buffer containing, e.g., 100 or 200 mg/mL mannitol (other excipients that are pharmaceutically acceptable, and in which vincristine remains stable for extended periods, can also be used), and adjusted to pH 3.5 to 5.5, or preferably pH 4.5 to pH 4.7. One of the vials contains a solution comprising sphingomyelin and cholesterol liposomes suspended in a 300 mM citrate buffer at, e.g., pH 4.0. Another vial or vials contains an alkaline phosphate buffer (e.g., pH 9.0) such as dibasic sodium phosphate, 14.2 mg/ml (20 ml/vial).

[0058] In one embodiment, the ingredients for the constitution of VSLI are provided separately in three vials containing (i) vincristine sulfate USP (5 mg/5 mL), which is equivalent to 4.5 mg/5 mL vincristine free base, and 500 mg/5 mL mannitol; (ii) sphingomyelin/cholesterol liposomes injection (SPLI) consisting of 73.5 mg/mL sphingomyelin, 29.5 mg/mL cholesterol, 33.6 mg/mL citric acid, 35.4 mg/mL sodium citrate, and not more than 0.1% ethanol; and (iii) Sodium phosphate injection (SPI) containing 355 mg/25 mL dibasic sodium phosphate and 225 mg/25 mL sodium chloride all prepared with water for injection.

[0059] The containers used in the methods of the invention are sterile and composed of any pharmaceutically acceptable substance (e.g., glass or plastic). There are a number of different vial types and sized that are commercially marketed by a number of different manufacturers (e.g., Wheaton Products, Thomas Scientific). In one embodiment, the components are constituted in a sterile vial with an average diameter of about 36.5 mm, and an average range of about 35.8 to about 37.3 mm.

[0060] Suitable dry block heaters, which provide a safe, dry, constant temperature source, are commercially available from a number of sources (e.g. Bibby Scientific Ltd, V&P Scientific, Inc., Fisher Scientific Inc., VWR Scientific, Thermolyne Inc.). Heat conductive inserts having one or more calibrated bores adapted to receive the container of constituting solution may be metal (e.g., anodized aluminum, copper) or other suitable heat conductive materials. Inserts containing bores of openings of the appropriate size can be readily obtained (e.g., V&P Scientific, Inc.), or manufactured using standard methods. In certain embodiments, the heat block contains openings that are between about 1-5%, or about 4.5%, 4.2%, 4.0%, 3.8%, 3.5%, 3.3%, 3.0%, 2.8%, 2.5%, 2.2%, 2.0%, 1.8%, 1.5%, 1.2% or 1.0% larger than the average length or diameter of the container containing the constituting solution. In some embodiments, the heat block contains cylindrical openings. In one embodiment, the openings are between 37.2 to 37.8 mm in diameter, or between about 37.4 to 37.6 mm in diameter.

[0061] In some embodiments, the constituting solution is heated for about 13 minutes, about 14 minutes, about 15 minutes, about 16 minutes, about 17 minutes at about 75°C. In one embodiment, the constituting solution is heated for about 14 minutes in at heat block equilibrated at 75°C.

[0062] The constituted VSLI may be admixed with a pharmaceutically acceptable diluent suitable for intravenous administration to the patient (e.g., dextrose, sodium chloride) which may be provided, for example in a pre-filled, sterile container (glass bottle, plastic bottle or plastic bag). In some embodiments, the volume of the patients calculated dose is removed from an infusion bag and replaced with the calculated volume of the constituted VSLI solution into an infusion bag, for example, where the final volume of the infusion container will be 100 mL. In one embodiment, the pharmaceutically acceptable diluents is of 5% Dextrose Injection or 0.9% Sodium Chloride Injection.

VSLI

[0063] The VSLI produced according to the methods described herein appears as a white to off-white, translucent

suspension, essentially free of visible foreign matter and aggregates. Typically, greater than about 95%, about 96%, about 97%, about 98% or more of the vincristine sulfate is encapsulated in the liposomes.

[0064] The VSLI produced according to the methods described herein contains total impurities of less than about 4.0%, 3.5%, 3.4%, 3.2%, 3.1% or 3.0%. In some embodiments, the VSLI contains less than about 2.0%, 1.8%, 1.7%, 1.6%, 1.5%, 1.4% or 1.3% N-desformylvincristine.

[0065] The VSLI produced according to the methods described herein has an average in vitro release rate (IVR) or in vivo release rate of at least about 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84% or about 85% within 72 hours.

[0066] Assays for determining the level of vincristine encapsulation, the levels of impurities and release rates of vincristine from liposomes are known in the art. See, for example, US Patents 5543152 and 5837282; Zhigalstev et al. J. Controlled Release 104:103-111, 2005); Puscaltau et al. Am. J. Health-Syst. Pharm. 62:1606-1612, 2005).

[0067] Generally, the VSLI produced according to the methods described herein contains vincristine sulfate at about 0.1 mg/mL to about 0.5 mg/mL. In certain embodiments, the vincristine sulfate is present at about 0.15 mg/mL to about 0.2 mg/mL. In one embodiment, the vincristine sulfate is present at about 0.16 mg/mL. In one embodiment, the VSLI contains 5 mg vincristine sulfate, 500 mg mannitol, 73.5 mg sphingomyelin, 29.5 mg cholesterol, 36 mg sodium citrate, 38 mg citric acid, 355 mg sodium phosphate, and 225 mg sodium chloride.

Dosage and Administration

[0068] VSLI prepared according to the methods described herein can be used to treat any type of cancer including primary, relapsed and refractory cancers. The patient or subject treated with the VLSI may be a variety of animals, including humans, non-human primates, avian species, equine species, canine species, feline species, bovine species, swine, lagomorphs, rodents, and the like. In certain embodiments, the VSLI is used to treat cancers of the blood and lymphatic systems including, but not limited to, lymphomas, leukemias and myelomas. In certain embodiments, the VSLI is used to treat tumors including, but not limited to neuroblastomas and brain cancers.

[0069] The VSLI can be used as a single agent or in combination with other chemotherapeutic agents, such as cyclophosphamide, doxorubicin and/or prednisone. In one embodiment, the VSLI is administered along with as cyclophosphamide, doxorubicin and prednisone as a liposomal CHOP formulation ("lipo-CHOP). In another embodiment, the VSLI is co-administered with at least one additional anti-tumor agent. In another embodiment, the additional anti-tumor agent is an anti-tumor monoclonal antibody, such as Oncoly™, Rituxan™, or Bexxar™. In another embodiment, the additional anti-tumor agent is an antisense drugs or an anti-tumor vaccine. In another embodiment, the VSLI is co-administered with a prophylactic or therapeutic treatment for neurotoxicity, such as gabapentin (Neurontin™).

[0070] Typically, the VSLI is prepared within about 24 hours of administration to the patient and is stored at room temperature (15°C to 30°C,) or refrigerated (2-8°C).

[0071] The VSLI is administered to the patient systemically by intravenous delivery. In one embodiment, the VSLI is administered by intravenous infusion over a period of, e.g., about 30 minutes, about 45 minutes, about 60 minutes, about 90 minutes or longer.

[0072] Typically, the VSLI is administered periodically, e.g., once every 7-28 days. In certain embodiments, the VSLI is administered once every 3, 5, 7, 10, 14, 21 or 28 days. In one embodiment, the VSLI is administered by intravenous infusion every 14 days. In another embodiment, the VSLI is administered by intravenous infusion every 7 days. As used herein, each administration of VSLI is considered one "course" of treatment.

[0073] The amount of VSLI administered per dose will depend on a number of factors, such as the medical history of the patient, the use of other therapies, and the nature of the disease (e.g., first line, relapsed or refractory cancer). Typically, the VSLI prepared according to the methods described herein is administered at a dosage of about 1.4 to about 2.4 mg/m². In certain embodiments, the VSLI is administered at a dose of about 1.5 mg/m², about 1.8 mg/m², about 2.0 mg/m², 2.1 mg/m², 2.2 mg/m², 2.3 mg/m² or 2.4 mg/m² (i.e., mg vincristine per m² body surface area). In one embodiment, the VSLI is administered at a dose of 2.25 mg/m² by intravenous infusion over about 60 minutes once every 7 days.

[0074] In other embodiments, the dose of VSLI may be temporarily interrupted and/or reduced during treatment. For example, in one embodiment, the dosage of VSLI administered to a patient portraying a Grade 3 peripheral neuropathy or persistent Grade 2 peripheral neuropathy may be discontinued for up to about 7 days, and then reduced to a dose of about 2mg/m² upon recovery to Grade 1 or 2. In another embodiment, the dosage administered to a patient portraying a persistent Grade 2 peripheral neuropathy, even after receiving a reduced dose, may be discontinued for up to 7 days, and then reduced to dose of 1.825 mg/m², or a dose of 1.5 mg/m².

[0075] The dosage of VSLI is determined by calculating the body surface area (BSA) of the subject according to well-known methods. For example, according to Mosteller's formula in which the BSA equals the square root of product of the weight of the subject in kg times the height in cm divided by 3600. The "normal" BSA in humans is generally taken to be 1.7 m² but also depends on other factors including the age and gender of the individual. For example:

EP 2 922 529 B1

- Average BSA for adult men: 1.9 m²
- Average BSA for adult women: 1.6 m²
- 5 • Average BSA for children (9 years): 1.07 m²
- Average BSA for children (10 years): 1.14 m²
- 10 • Average BSA for children (12-13 years): 1.33 m²

(Mosteller RD. Simplified calculation of body-surface area. N Engl J Med 1987;317:1098)

EXAMPLES

15 Example 1

[0076] The temperature profile of the VSLI vial solution was investigated during the heating with the dry block process and compared with that of the temperature profile observed when heating with a water bath following the approved label instructions for Marqibo® (FDA/cder Reference ID: 3172211, August 2012).

20 Equipment and Materials

[0077]

- 25 • Marqibo® kit constituted VSLI, lot NT 268035 (contents of partially used vials combined into one vial)
- Techne Dri-block® DB-3 heater equipped with 1.480" diameter well and thermometer pocket (Bibby Scientific Limited).
- Digital thermometers ; accurate to $\pm 1^{\circ}\text{C}$ in the range of $0^{\circ}\text{-}100^{\circ}\text{C}$
- Isotemp 202 #00947 water bath (Fisher Scientific)
- 30 • Fluke 726 #914002 thermo-couple temperature calibrator (Fluke Corporation)

Procedure

35 [0078] Temperature profile measurements were generated by recording the solution temperature inside the vial after being placed in the heating apparatus (*i.e.*, dry block or water bath). Time zero was the point where the vial was placed in the heating apparatus. The following procedure was used:

40 1. The components, VSI and SCLI, were combined into a single SPI vial (Swiss Precision Instruments, Inc.). A digital thermocouple was inserted through the septum of the vial and held approximately 5 mm from the bottom surface of the vial and positioned in the middle of the liquid solution.

45 2. The dry block heater was used with a block containing a 1.480 inch vial container hole. The block temperature was monitored by placing a thermometer into the block's thermometer hole, which is situated in proximity to the vial container hole. The block heater was set to a temperature of 75°C and allowed to warm until the block thermometer read $75 \pm 2^{\circ}\text{C}$. The heated block was equilibrated for a minimum of 15 minutes at $75 \pm 2^{\circ}\text{C}$. The vial was then inserted into the well of the $75 \pm 2^{\circ}\text{C}$ equilibrated block for 14 minutes ± 15 seconds, and then removed. The constituted vial was allowed to come to ambient temperature by placing in ambient conditions for about 60 minutes. The procedure was repeated twice using the same vial.

50 3. Vial internal liquid temperature, and block temperatures were recorded at 1 minute intervals (or as noted) and tabulated in Table 1.

55 4. For comparison, the water bath was allowed to heat until the water temperature was $65 \pm 5^{\circ}\text{C}$. The water bath was equilibrated for a minimum of 15 minutes. The vial containing constituted VSLI was then inserted into the water bath for 10 minutes ± 1 minute, and then removed. The constituted vials were allowed to come to ambient temperature.

5. Vial internal liquid temperature, time and water temperature were recorded and tabulated in Table 1.

Results and Discussion

[0079] The temperature profile of heating the liquid contents of a constituted VSLI vial with a dry block equilibrated at

EP 2 922 529 B1

75° ± 2°C, demonstrate an even and gradual heating rate to 65° ± 5°C. The results tabulated in Table 1 and Figure 1 show that the dry block heated the liquid vial contents at a mean rate of 3.26°C/minute as compared to the water bath, which heated the vial contents at a mean rate of 4.21°C/minute. The desired temperature of 65° ± 5°C was achieved in 14 minutes in the dry block compared to the water bath which took 10 minutes. With both heating apparatuses, once the vial was removed from the heating source there was gradual cooling. The temperature remained within 59-65°C for 3-4 minutes following removal from the dry block and 1-2 minutes following removal from the water bath. With both apparatuses, the vial was exposed to 50-65°C for at least 20 minutes with the dry block and 15 minutes with the water bath. Following heating in either apparatus, the solutions remained visually identical: a white to off-white, translucent suspension essentially free of visible foreign matter and aggregates.

Table 1. Constitution Temperature Profile*

Time	Internal Temp HB	Block Temp	Internal temp HB	Block temp2	Internal temp WB	Water Bath
0	20.3	75.3	22.8	75.4	20.9	63.8
1	25.6	74.7	29.9	74.8	35.4	63.8
2	31.6	74.0	36.1	74.0	45.6	63.9
3	37.0	73.5	41.3	73.6	51.7	63.4
4	41.9	73.3	45.5	73.4	56.1	63.7
5	46.2	73.2	49.1	73.4	58.8	63.6
6	49.8	73.2	52.4	73.4	60.3	64.0
7	53.0	73.3	55.2	73.4	61.3	64.4
8	55.6	73.4	57.5	73.5	62.2	64.0
9	57.9	73.6	59.7	73.8	62.7	63.8
10	60.8	73.8	61.4	73.9	63.0	63.8
11	62.1	73.9	62.8	74.1	59.0	NR
12	63.3	74.1	64.4	74.2	56.6	NR
13	64.6	74.1	65.4	74.3	54.8	NR
14	65.8	74.3	66.4	74.4	53.1	NR
15	65.6	NR	66.1	NR	52.0	NR
16	64.1	NR	63.7	NR	51.2	NR
17	62.7	NR	NR	NR	50.3	NR
18	61.2	NR	60.6	NR	49.3	NR
19	59.8	NR	59.3	NR	48.7	NR
20	58.6	NR	58.0	NR	48.0	NR
21	57.4	NR	56.5	NR	NR	NR
22	56.1	NR	55.3	NR	NR	NR
23	55.0	NR	54.2	NR	NR	NR
24	53.9	NR	53.2	NR	NR	NR
25	52.8	NR	NR	NR	44.4	NR
26	51.7	NR	NR	NR	NR	NR
27	50.8	NR	NR	NR	NR	NR
28	49.8	NR	NR	NR	NR	NR
	NR	NR	NR	NR	NR	NR
33	45.6	NR	NR	NR	NR	NR

EP 2 922 529 B1

(continued)

Time	Internal Temp HB	Block Temp	Internal temp HB	Block temp2	Internal temp WB	Water Bath
38	42.3	NR	NR	NR	NR	NR
43	39.4	NR	NR	NR	NR	NR
48	37.3	NR	NR	NR	NR	NR
53	35.3	NR	NR	NR	NR	NR
58	33.9	NR	NR	NR	NR	NR
60	33.3	NR	NR	NR	NR	NR

*Internal Temp HB = internal temperature of vial contents heated in the dry block
 Internal Temp WB = internal temperature of the vial contents heated in the water bath
 NR= Not recorded

Conclusion

[0080] This study demonstrated that the dry block proved a suitable temperature heating profile that allows the VSLI vials internal liquid temperature to achieve $65^{\circ} \pm 5^{\circ}\text{C}$ within 14 minutes, and provided a heating exposure in the $50\text{-}65^{\circ}\text{C}$ range of 20 minutes. This compares to the heating the vials in a water bath, which achieves an internal liquid temperature of $65^{\circ} \pm 5^{\circ}\text{C}$ in 10 minutes, and an overall heating exposure in the $50\text{-}65^{\circ}\text{C}$ range of 15 minutes. The rate of heating for both methods was gradual and even. The dry block set at $75^{\circ} \pm 2^{\circ}\text{C}$ produced a heating rate of 3.26°C per minute, and the water bath set at $65^{\circ} \pm 5^{\circ}\text{C}$ produced a rate of 4.21°C per minute. The heating leveled off with the water bath, while the rate of the heating in the dry block continued at a steady rate toward the $75^{\circ} \pm 2^{\circ}\text{C}$ set point. Cooling to ambient temperature took about 60 minutes once the vials were removed from either heating apparatus. These heating profiles suggest that the near quantitative encapsulation of vincristine is a thermodynamic process which is dependent on the overall exposure to temperatures that promote membrane encapsulation rather than the kinetics of achieving those conditions.

[0081] In summary, the dry block and water bath can provide a thermodynamic profile that allows encapsulation of vincristine into the sphingomyelin cholesterol liposomes for the efficient preparation of VSLI.

Example 2

[0082] The levels of vincristine degradant products of VSLI constituted using a dry heat block were investigated.

Equipment and Materials:

[0083]

- Techne DB-3 Dri-Block® equipped with 1.480" diameter well and thermometer pocket.
- Thermometer with a diameter no greater than 7 mm, and accurate to $\pm 1^{\circ}\text{C}$ in the range of $0^{\circ}\text{-}100^{\circ}\text{C}$.
- Calibrated stopwatch or timer
- Micrometer (0-2") or equivalent.
- 30 Marqibo® Kits, Lot # TTX0611 (Talon Therapeutics, Inc.)

Procedure

[0084] Vials from 30 Marqibo® kits having SPI vials with the maximum and minimum outer diameters were used in the study. The diameter of the SPI vials was measured and recorded to the nearest 0.001". Results are shown in Table 2.

Table 2. Vial Identification and SPI Vial Diameter

Vial Identification	SPI Vial Diameter (± 0.0001 in.)	Study Allocation
1	1.4350	
2	1.4360	

EP 2 922 529 B1

(continued)

5
10
15
20
25
30
35
40
45
50
55

Vial Identification	SPI Vial Diameter (±0.0001 in.)	Study Allocation
3	1.4340	
4	1.4350	
5	1.4490	
6	1.4455	
7	1.4330	
8	1.4370	
9	1.4350	
10	1.4315	
11	1.4405	
12	1.4545	kit 2
13	1.4335	
14	1.4370	
15	1.4430	
16	1.4380	
17	1.4345	
18	1.4305	kit 1
19	1.4330	
20	1.4455	
21	1.4360	
22	1.4325	
23	1.4425	
24	1.4465	
25	1.4475	
26	1.4325	
27	1.4420	
28	1.4440	
29	1.4315	
30	1.4330	

[0085] Two vials were selected for constitution. The vial having a diameter closest to or equal to 1.41 inches ("vial 1"), the lower end of the allowed SPI vial diameter had a measured diameter of 1.4305 inches. The vial having a diameter closest to or equal to 1.47 inches ("vial 2"), the upper end of the allowed SPI vial diameter, was measured to have a diameter of 1.4545 inches.

[0086] The selected kits were constituted as described above and tested for Vincristine Sulfate, Related Compounds and particle size and distribution following adapted Vincristine sulfate injection USP methods.

[0087] The two study kits were constituted using the above instructions, except that instead of the water bath, the Dri-Block heater was used with a block containing a 1.480 inch vial container hole. The block temperature was monitored by placing a thermometer into the block's thermometer hole which is situated in proximity to the vial container hole. The block heater was set to a temperature of 75°C and allowed to heat until the block thermometer read 75 ± 2°C. The heated block was then equilibrated for a minimum of 15 minutes (time recorded). The conditions are noted in Table 3. Each vial was then inserted into the 75 ± 2°C heated block for 14 minutes ± 15 seconds (time recorded), and then removed and allowed to come to ambient temperature by placing the vial in ambient conditions over about 60 minutes.

EP 2 922 529 B1

[0088] Time and block temperatures were recorded as indicated in Table 4 during constitution. Analytical results were recorded in Tables 5, 6 and 7.

Table 3. Dry Block Temperature Equilibration

	Time	Time between Successive Readings
Dry Block Set to 75°C	8:35 AM	
First instance thermometer reads 75 ± 2°C	8:46 AM	73.0°C
15 minute equilibration	9:01 AM	75.2°C

Table 4. Dry Block Constitution Parameters

Vial ID	SPI Vial Diameter	Temperature T=0 mins.	Temperature T=1 mins.	Temperature T=5 mins.	Temperature T=14 mins.	Time at Removal
		75±1°C	For info.	For info.	75±1°C	14 min ± 15 sec
12	1.4545	75.2°C	74.5°C	73.2°C	74.2°C	9:24AM
18	1.4305	75.2°C	74.6°C	73.2°C	74.3°C	10:02AM

Table 5. Total & Free Vincristine Results

Kit ID	Total Vincristine
Kit 1	102.10%
Kit 2	102.14%

Table 6. Related Compounds Results

Kit ID	N-Desformylvincristine	Any other compound
Kit 1	1.314	0.572
Kit 2	1.345	0.574

Table 7. Particle Size Distribution

Kit ID	Mean Diameter	D ₂₅	D ₉₀
Kit 1	108 nm	90 nm	139 nm
Kit 2	107 nm	91 nm	138 nm

Results and Discussion

[0089] The constitution of VSLI was achieved using constitution vials having a diameter of 1.4305 and 1.4545 inches using the Dri-Block heater. These represented vials closest to the 1.41 inch lower limit and 1.47 inch upper limits allowed for vial diameters. During the 14 minute incubation of the VSLI vials in the heating block, the block temperature dropped no more than 1 degree due to temperature equilibration between the space gap between the block well diameter and either diameter of vials. This kinetics of the heat transfer did not affect the preparation of VSLI. After 14 minutes of exposure to the Dri-Block heat equilibrated at 75°C, the resulting constituted VSLI from both vials achieved greater than 97% vincristine encapsulation. The incubation using the Dri-Block resulted in an encapsulation efficiency averaging 2.175% free vincristine. No new or increased impurities were observed with the Dri-Block heating profile. The principle

EP 2 922 529 B1

degradant, N-desformylvincristine, was observed at an average of 1.33%, with no other impurity greater than 0.574%, and total impurities of no more than 3.10%. The particle size distribution was consistent with VSLI specifications with an average diameter of 107.5 nm diameter and mean D_{25} of 90.5 nm and D_{90} of 138.5 nm, VSLI prepared with Dri-Block heating released approximately 84 percent of the vincristine by 72 hours by IVR analysis..

[0090] In conclusion, VSLI constituted using the dry block heater equilibrated at $75 \pm 2^\circ$ with an incubation period of 14 minutes \pm 15 seconds encapsulated greater than 99% of vincristine in the sphingomyelin-cholesterol liposomes, and no anomalies were recorded during this experiment. The data establish a dry block constitution temperature profile that leads to a product that efficiently encapsulates vincristine and demonstrates that the dry block heater can be substituted for a water bath in the constitution of VSLI.

Example 3

[0091] In this study the levels of vincristine degradant products were measured to provide a range of constitution time using the dry block procedure.

Equipment and Materials

[0092]

- Dri-Block® equipped with 1.476" (± 0.004) diameter well and thermometer pocket.
- Thermometer with a diameter no greater than 7 mm, and accurate to $\pm 1^\circ\text{C}$ in the range of 0° - 100°C .
- Calibrated stopwatch or timer
- Marqibo® Kits, Lot # TTX0611 (Talon Therapeutics, Inc.)

Procedure

[0093] Three Marqibo® Kits were selected at random and constituted by heating in the dry block at three different times (13, 14 and 15 minutes, respectively) at 75°C . The constituted vials were tested for Total and Free Vincristine Sulfate, Related Compounds, particle size and distribution using adapted vincristine sulfate Injection USP methods.

[0094] The study kits were constituted using the instructions as described above except that, instead of a water bath, the Dri-Block® heater was used with a block containing a 1.476 inch (± 0.004 ") vial container hole. The block temperature was monitored by placing a thermometer into the block's thermometer hole which is situated in proximity to the vial container hole. The block was set to a temperature of 75°C and allowed to heat until the thermometer in the block reads $75 \pm 2^\circ\text{C}$. The heated block was then equilibrated for a minimum of 15 minutes. The conditions were recorded in Table 9. Each vial was then inserted into the $75 \pm 2^\circ\text{C}$ heated block for 13 minutes \pm 15 seconds, 14 minutes \pm 15 seconds, and 15 minutes \pm 15 seconds, respectively. The vials were then removed and placed at ambient temperature. The constituted vials were allowed to cool at ambient temperature for at least 60 minutes prior to testing.

[0095] Time and block temperatures were recorded as indicated in Tables 9 and 10 during constitution. Analytical results were recorded in Tables 11, 12 and 13.

Table 9a. Dry Block Temperature Equilibration (Vial 1)

	Time	Time between Successive Readings
Dry Block Set to 75°C	8:20 AM	
First instance Thermometer reads $75 \pm 2^\circ\text{C}$	8:48 AM	NA
15 minute equilibration*	9:03 AM	15 mins.
*Temperature at end of 15 minute equilibration period: 75.2°C		

Table 9b. Dry Block Temperature Equilibration (Vial 2)

	Time	Time between Successive Readings
Dry Block Set to 75°C	9:17 AM	
First instance Thermometer reads $75 \pm 2^\circ\text{C}$	9:17 AM	NA

EP 2 922 529 B1

(continued)

	Time	Time between Successive Readings
15 minute equilibration*	9:32 AM	15 mins.
*Temperature at end of 15 minute equilibration period: 75.2°C		

Table 9c. Dry Block Temperature Equilibration (Vial 2)

	Time	Time between Successive Readings
Dry Block Set to 75°C	9:47 AM	
First instance Thermometer reads 75 ± 2°C	9:47 AM	NA
15 minute equilibration*	10:02 AM	15 mins.
*Temperature at end of 15 minute equilibration period: 75.1°C		

Table 10. Dry Block Constitution Parameters

Vial	SPI Vial Diameter	Temp T=0	Temp T=1 mins.	Temp T=5 mins.	Temp T=13 mins.	Temp T=14 mins.	Temp T=15 mins.
		75±1°C	For info.	For info.	± 15 secs.	± 15 secs.	± 15 secs.
1	1.4490	75.2°C	74.6°C	73.2°C	74.2°C		
2	1.4360	75.2°C	74.5°C	73.2°C		74.1°C	
3	1.4355	75.2°C	74.6°C	73.3°C			74.2°C

Table 11. Total & Free Vincristine Results

Kit ID	Total Vincristine
Kit 1	100.91
Kit 2	100.59
Kit 3	100.43

Table 12. Related Compounds Results

Kit ID	N-Desformylvincristine	Any other compound
Kit 1	1.498	0.590
Kit 2	1.506	0.587
Kit 3	1.464	0.593

Table 13. Particle Size Distribution

Kit ID	Mean Diameter	D ₂₅	D ₉₀
Kit 1	107 nm	91 nm	137 nm
Kit 2	106 nm	90 nm	137 nm
Kit 3	107 nm	90 nm	138 nm

Results and Discussion

[0096] One constituted kit each was placed in an equilibrated heat block at 75°C for 13, 14 and 15 minutes respectively. All the sample times produced encapsulated vincristine, and there were no significant differences in test results noted between the three vials. Greater than 97% vincristine encapsulation was observed with all three vials using the Dri-Block resulting in an encapsulation efficiency with a maximum 2.3% free vincristine. No new or increased impurities were observed with the Dri-Block heating profile. The principal degradant, N-desformylvincristine, was observed at a maximum of 1.51% with no other impurity greater than 0.59% and total impurities of no more than 3.3%. The particle size distribution was consistent with VSLI specifications with an average diameter of 107 nm diameter and mean D_{25} of 90 nm and D_{90} of 137 nm.

[0097] In conclusion, VSLI constituted with the substitution of the water bath with a Dri-Block equilibrated at $75 \pm 2^\circ \text{C}$ with an incubation period of 13 to 15 minutes (± 15 seconds) encapsulated vincristine efficiently and no anomalies were recorded during the conduct of the experiment. The data establishes a Dri-Block constitution temperature profile that leads to efficient VSLI constitution and shows that the Dri-block heater can be substituted for a water bath in the constitution of the VSLI.

[0098] It is understood that the examples and embodiments described herein are for illustrative purposes only.

Claims

1. A method of preparing a pharmaceutically acceptable liquid composition comprising liposome-encapsulated vincristine which is free of substantial degradation products, the method comprising:

(a) constituting in a single vial

(i) a first solution comprising vincristine sulfate at a concentration of 1 mg/ml to 5 mg/ml, wherein the first solution has a pH of 3.5 to 5.5; and

(ii) a second solution comprising sphingomyelin/cholesterol liposomes at a low pH;

(b) raising the pH of the constituting solution in the single vial to a pH of 7.0 to 7.5;

(c) heating the single vial comprising the constituting solution in a dry heat block equilibrated at 75°C for at least 13 to 18 minutes, wherein said heat block comprises one or more bores 1-5% larger than the average length or diameter of the single vial to produce a solution comprising constituted liposome encapsulated vincristine; and

(d) equilibrating the constituted solution to room temperature.

2. The method of claim 1, wherein the pH of the second solution comprising the liposomes is 4.0.

3. The method of claim 2, wherein the second solution further comprises a citrate buffer.

4. The method of claim 1, wherein the pH of the constituting solution is raised by the addition of a third solution comprising a buffer at a pH of 9.0.

5. The method of claim 4, wherein the third solution comprises sodium phosphate buffer.

6. The method of claim 1, wherein the constituting solution comprises a concentration of 0.1/1.0 to 0.2/2.0 weight vincristine sulfate to weight lipid.

7. The method of claim 6, wherein the concentration of vincristine sulfate in the constituted solution is 0.1 mg/mL to 0.5 mg/mL.

8. The method of claim 7, wherein the concentration of vincristine sulfate in the constituted solution is at 0.15 mg/mL to 0.2 mg/mL.

9. The method of claim 4, wherein the first solution comprises vincristine sulfate USP (5 mg/5 mL), which is equivalent to 4.5 mg/5 mL vincristine free base, and 500 mg/5 mL mannitol, the second solution comprises sphingomyelin/cholesterol liposomes consisting of 73.5 mg/mL sphingomyelin, 29.5 mg/mL cholesterol, 33.6 mg/mL citric acid, 35.4 mg/mL sodium citrate, and the third solution comprises 355 mg/25 mL dibasic sodium phosphate and 225 mg/25 mL sodium chloride.

Figure 1. Constitution Temperature Profile

