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(54) Title: TOPICAL DRUG DELIVERY USING PHOSPHATIDYLCHOLINE

(57) Abstract: The present invention relates to compositions and methods for transdermal drug delivery comprising formulating a phosphatidylcholine carrier composition containing the drug and applying the composition to the skin.

TOPICAL DRUG DELIVERY USING PHOSPHATIDYLCHOLINE

Prior Applications

[0001] Applicant claims priority benefits of U.S. Utility Application, awaiting assignment of serial number, filed on May 30, 2003, and of U.S. Provisional Patent Application Serial No. 60/384,597 filed May 31, 2002.

Field Of The Invention

Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

[0002] The present invention relates to a topical drug delivery composition and method. More specifically, this invention relates to topical drug delivery compositions and methods using phosphatidylcholine.

Background Of The Invention

[0003] Transdermal drug delivery systems may be designed to act locally at the point of application or to act systemically by entering the body's blood circulation. In these systems, delivery may be achieved by direct topical application of a substance or drug in the form of an ointment or the like, or by adhesion of a patch with a reservoir that holds the drug and releases it to the skin in a time-controlled fashion.

[0004] Transdermal delivery systems for agents such as drugs, pain relieving compounds, vitamins, and skin improving compounds have been in use for a number of years. However, these systems have typically only been useful for transdermal delivery of relatively small molecules. The skin's porous structure permits such small molecules to pass from the epidermis to the dermis

via diffusion. These transdermal delivery systems such as creams have been developed for use with analgesics and skin refining compounds. Transdermal systems using a patch have been developed for nicotine and estrogen therapies. Estradiol technologies are described in U.S. Patent No. 6,521,250 to Meconi, et al.. However, large molecules, such as insulin, are not able to diffuse through the skin. To date there has not been an effective and economical method to transport such molecules through the epidermis to enter the bloodstream via the dermal vasculature.

[0005] It has been proposed that molecules, potentially including larger molecules, can be transported through the skin when such molecules are contained within spherical vesicles, variously called microparticles, microspheres, liposomes, lipid vesicles, transfersomes, formed by hydrating a phospholipid. The resulting vessels are water–insoluble and are dispersed and suspended in a liquid base material which is applied to the skin to deliver the drug. U.S. Patent No. 6,165,500 to Cevc discloses "transfersomes," which are vesicles containing both a lipid and surfactant, to achieve transdermal delivery, based on a theory that osmotic pressure will drive the transfersomes through the dermis. Other solutions have been proposed, including the use of ultrasound devices to generating shock waves to enlarge pores, use of electric current to drive substances across skin, and the use of microneedles to pierce skin and deliver drugs into bloodstream. (See *More Than the Patch: New Ways to Take Medicine Via Skin*, New York Times, July 2, 2002, page F5.

[0006] There remains a need for a transdermal drug delivery system with the improved skin permeability and ability to transport a wider range of substances or drugs. This problem is particularly apparent in the transdermal delivery of substances composed of large molecules, such as polypeptides or proteins, which do not readily pass through the pores of the skin. Absent such a

transdermal drug delivery system, the use of injections to deliver these substances will remain the conventional dosage method, despite the pain, complicated administration and general invasiveness involved therein.

Summary Of The Invention

[0007] The present invention relates to compositions and methods of transdermal drug delivery comprising formulating a composition containing the drug in a crystallized phosphatidylcholine carrier and applying the composition to the skin.

According to a first aspect, the present invention provides a composition comprising crystallized phosphatidylcholine and drug molecules entrapped within said phosphatidylcholine.

According to a second aspect, the present invention provides a method for topically administering a macromolecular drug comprising formulating a composition containing the drug in a crystal phosphatidylcholine carrier and applying the composition to the skin.

According to a third aspect, the present invention provides a method for administering insulin to a patient comprising topically applying a composition comprising a crystal phosphatidylcholine carrier and insulin to skin of the patient.

According to a fourth aspect, the present invention provides use of a drug in a crystal phosphatidylcholine carrier in the manufacture of a medicament for topical administration to the skin.

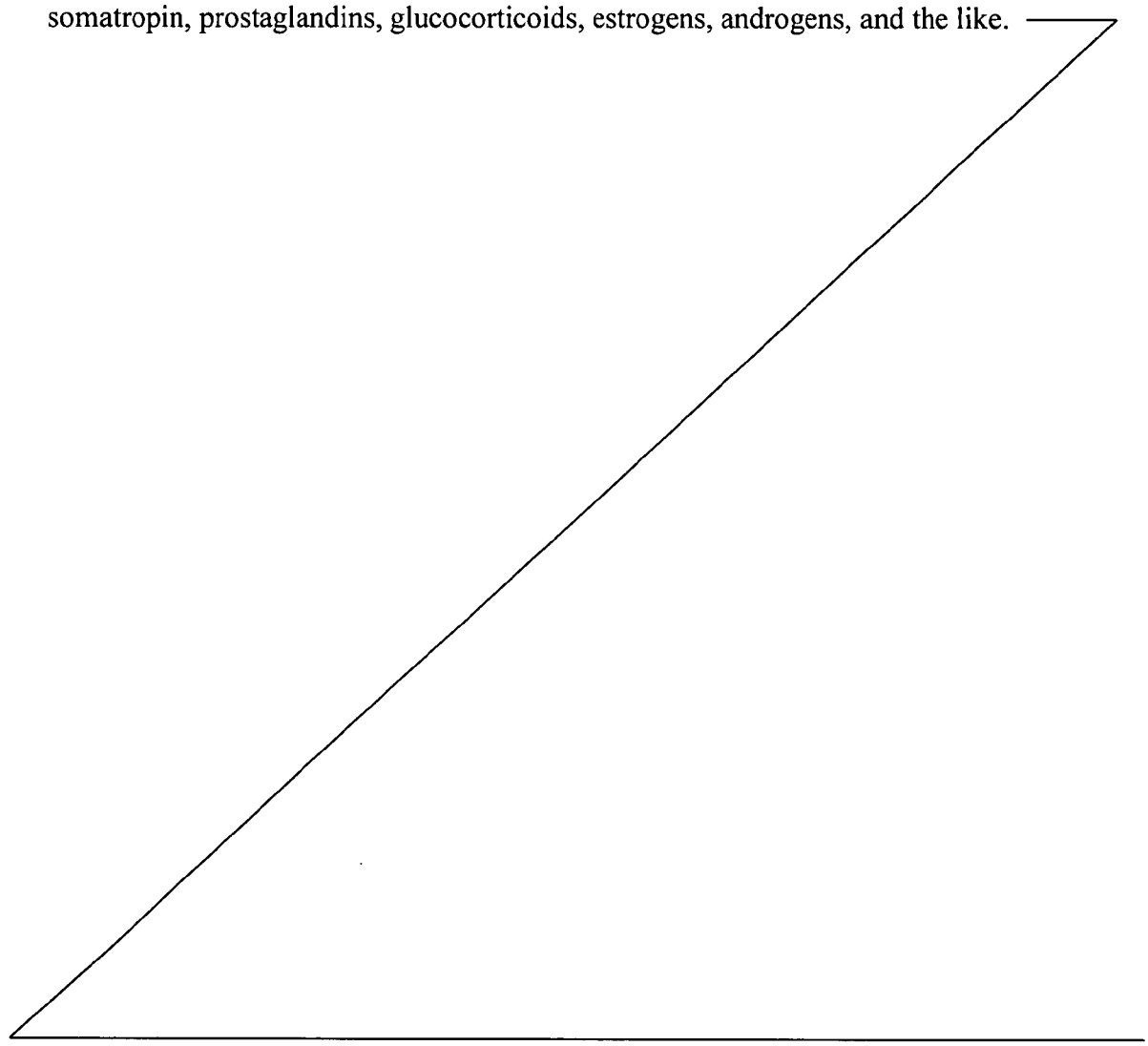
According to a fifth aspect, the present invention provides use of a crystal phosphatidylcholine carrier and insulin in the manufacture of a medicament for topical application to the skin of a patient.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", "consist", "consisting" and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

Detailed Description

[0008] Phosphatidylcholine is used as a carrier for the topical drug delivery of macromolecules in the practice of this invention. Phosphatidylcholine is a basic component of cell membrane bilayers and the main phospholipid circulating in the plasma. Phosphatidylcholine is highly absorbable and supplies choline which is needed to facilitate movement of fats and oils across and maintain cell membranes in animals.

[0009] Phosphatidylcholine compositions (herein abbreviated "PC compositions") of the present invention are formulated to contain macromolecules soluble in PC, which are then applied to skin for transdermal delivery of the macromolecules. PC compositions of the invention are efficacious in the delivery of macromolecular drugs that are conventionally administered such as insulin and somatropin, prostaglandins, glucocorticoids, estrogens, androgens, and the like.



[00010] It is an advantage of the invention that topical delivery is easier and pleasanter as an administration route than injections, particularly for drugs such as insulin that must be given to patients over a period of time, or for a lifetime. Furthermore, unlike oral administration where a substantial amount of the drug can be destroyed in the digestive process, the drugs in a topical application are not wasted. Topical application allows a steady diffusion of the drug to the desired target area without the cyclic dosages typical of orally or parenterally administered drugs.

[00011] Typical phosphatidylcholine compositions of the present invention are nonpolar and contain about 85% phosphatidylcholine. By "phosphatidylcholine" is meant a mixture of stearic, palmitic, and oleic acid diglycerides linked to the choline ester of phosphoric acid, commonly called lecithin. Many commercial lecithin products are available, such as, for example, Lecithol®, Vitellin®, Kelecin®, and Granulestin® because lecithin is widely used in the food industry. Compositions of the invention can contain synthetic or natural lecithin, or mixtures thereof. Natural preparations are preferred because they exhibit desirable physical characteristics and are both economical and nontoxic.

[00012] The macromolecular drugs are mixed with the PC composition under conditions to become entrapped in a phosphatidylcholine bilayer. Phosphatidylcholine forms a bilayer entrapping the macromolecular drug, which may be a polypeptide, contributing to the stability of the active molecule and enhancing penetration. The PC composition therein comprises a carrier-drug combination to be applied topically.

[00013] While not wishing to be bound by any particular theory, it is believed that the following mechanism illustrates how the PC composition acts to efficiently transport the drug across the epidermis, maximizing penetration of the

drug. The PC composition, in liquid crystal phase, is loosely arranged in multilamellar fashion, with the drug being bonded and entrapped within the lipid bilayers formed by the PC composition. This forms a loosely arranged, yet stable, PC composition carrier-drug complex. When placed on the epidermis, the carrier-drug complex begins to diffuse through the epidermis. The phosphatidylcholine molecular chain remains loosely linked with the drug molecular chain and the diffusing phosphatidylcholine molecules"drag" the drug molecules along as they pass through the skin layers. Moreover, the phosphatidylcholine molecules may begin to separate from the loosely arranged carrier-drug complex and become integrated into the dermis. As the phosphatidylcholine molecules separate from the crystallized phophoslipid bilayer structure of the carrier-drug complex the drug molecules are released. As these drug molecules are released, they are now within into the dermis and may enter the dermal vasculature so they may act accordingly in the bloodstream. Drug molecules which were once too large to diffuse, by themselves, into the pores of the epidermis, have instead been forced through the epidermis by phosphatidylcholine carriers which naturally enter and integrate into lipid bilayer structures within the cells of the epidermis and/or dermis and resultantly are required to release their bonds to the drug molecules and set them free within the dermis.

[00014] Preferred PC compositions comprise phosphatidylcholine in crystal phase to increase fluidity of the lipid bilayer formed. By reducing rigidity and loosening the phospholipid bilayer of the PC composition, larger molecules may embed therein and penetration of the carrier-drug composition by the cell membrane is facilitated. The skin is more permeable to the fluid, less structured lipid bilayer of the PC/carrier-drug composition applied thereon than to the drug by itself, or entrapped in an organized, arranged vesicle such as a liposome.

The loosely packed lipid bilayer of the crystallized carrier-drug composition integrates into the cell membrane, and as a result, has transported the drug so it can enter the bloodstream to act upon the body. The PC composition may be a multilamellar liquid crystal phase or a liquid crystal phase suspension in water which may be converted to multilamellar liquid lipid vesicles.

[00015] In preferred embodiments, nonpolar preparations of phosphatidylcholine are formulated to contain adjunct ingredients, *e.g.*, lipoic acid and ascorbyl palmitate, in addition to the macromolecular drug. The adjunct ingredients act synergistically to help to minimize degradation and thus preserve the integrity of the insulin polypeptide chains, and to enhance transdermal penetration of active insulin so that it can be absorbed by the dermal vasculature.

[00016] Preferred PC compositions of the invention contain some polyenylphosphatidylcholine (herein abbreviated "PPC") to enhance epidermal penetration. By "polyenylphosphatidylcholine" is meant any phosphatidylcholine bearing two fatty acid substituents, wherein at least one is an unsaturated fatty acid with at least two double bonds such as linoleic acid. Preferred PPCs contain a mixture of substitutents such as those found in natural products such as soybean lecithin, which contains 11.7% palmitic, 4.0% stearic, 8.6% palmitoleic, 9.8% oleic, 55.0% linoleic, and 4.0% linolenic acid substituents and is a by-product of soybean oil manufacture.

[00017] Certain types of soybean lecithin, for example, contain higher levels of polyenylphosphatidylcholine, with dilinoleoylphosphatidylcholine (18:2-18:2 phosphatidylcholine) as the most abundant phosphatidylcholine species, than conventional food grade lecithin, and are useful in formulating phosphatidylcholine insulin compositions of the invention. Alternatively, conventional soybean lecithin is enriched with PPC by adding soybean extracts containing high levels

of PPC. As used herein, this type of phosphatidylcholine is called "PPC-enriched" phosphatidylcholine, even where the term encompasses lecithin obtained from natural sources exhibiting PPC levels higher than ordinary soybean varieties. These products are commercially available from American Lecithin, Rhône-Poulenc and other lecithin vendors. American Lecithin markets its products with a "U" designation, indicating high levels of unsaturation; Rhône-Poulenc's product is a soybean extract containing about 42% dilinoleoylphosphatidylcholine and about 24% palmitoyllinoleylphosphatidylcholine (16:0-18:2 PC) as the major PC components.

[00018] PC compositions are used for transdermal polypeptide delivery in some preferred embodiments. Polypeptide drugs that are delivered transdermally using formulations can be small, *e.g.*, ocytocin and vasopressin nonapeptides or large, *e.g.*, insulin, gonadotropin, and somatropin. PC compositions of the invention deliver drugs including, but are not limited to, oxytocin, vasopressin, insulin, somatotropin, calcitonin, chorionic gonadotropin, menotropins, follitropins, somatostatins, progestins, and combinations of any of these. These drugs are readily available from a variety of commercial sources. Insulin, for example, is marketed under the tradenames Humulin®, Novolin®, Humalog®, and Inutral®. Somatotropin is marketed under the tradenames Gentropin®, Humatrope®, Nutropin®, and Serostim®. Some of these products and other polypeptides contain porcine sequences. Preferable compositions of the invention are preferably formulated with recombinant human polypeptides. It is an advantage of the invention that PC insulin compositions are formulated with commercially available ingredients.

[00019] One, non-limiting, example of an insulin topical preparation was formulated by combining 0.75% methyl paraben with a commercial phosphatidylcholine preparation marketed as a solution denoted NAT-8729

(containing PEG-400 at 40% and P.G. at 5%) by mixing for an hour or more to emulsify. To this is slowly added Dow Corning Fluid 200-5 or 10 cst (1% by weight), the formulation is mixed, and then Dow Corning Fluid 190 (1% by weight) is slowly added, and the formulation is further mixed to provide a stock insulin carrier. Prior to topical administration, insulin is added at a level of about 3.8 mg/ml to provide about 100 insulin units per ml.

[00020] Another, non-limiting, example of a pituitary growth hormone (somatotropin) composition was formulated with 85% phosphatidylcholine to which lipoic acid and ascorbyl palmitate was added as antioxidants. Somatotropin readily dispersed in phosphatidylcholine and remained stable in it. Growth hormone appeared to penetrate the skin well when the composition was topically applied.

[00021] It is appreciated that the foregoing is illustrative and not limiting of the invention, and that various changes and modifications to the preferred embodiments described above will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit and scope of the present invention, and it is therefore intended that such changes and modification be covered by the following claims.

2003231943 18 Jan 2006

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A composition comprising crystallized phosphatidylcholine and drug molecules entrapped within said phosphatidylcholine.

2. The composition of claim 1, wherein the drug molecules comprise polypeptides.

3. The composition of claim 1, wherein the drug molecules are selected from the group consisting of oxytocin, vasopressin, insulin, somatotropin, calcitonin, chorionic gonadotropin, menotropins, follitropins, somatostatins, progestins, and combinations of any of these.

4. The composition of claim 1, wherein the composition contains about 85% phosphatidylcholine.

5. The composition of claim 1, wherein the phosphatidylcholine is soybean lecithin.

6. The composition of any one of claims 1, 2, 3, or 4 further comprising polyenylphosphatidylcholine.

7. The composition of any one of claims 1, 2, 3, 4 or 5 further comprising one or more of ascorbyl palmitate and lipoic acid.

8. A method for topically administering a macromolecular drug comprising formulating a composition containing the drug in a crystal phosphatidylcholine carrier and applying the composition to the skin.

9. A method according to claim 8, wherein the composition contains about 85% phosphatidylcholine.

10. A method according to claims 8 or 9, wherein the phosphatidylcholine is soybean lecithin.

11. A method according to any one of claims 8, 9, or 10, wherein the phosphatidylcholine contains polyenylphosphatidylcholine.

12. A method according to claim 8, wherein the macromolecular drug is a polypeptide.

13. A method according to claim 12, wherein the polypeptide is selected from the group consisting of oxytocin, vasopressin, insulin, somatotropin, calcitonin, chorinic gonadotropin, menotropins, follitropins, somatostatins, progestins, and combinations of any of these.

14. A method according to claim 12, wherein the polypeptide is somatotropin.

15. A method according to claim 12, wherein the polypeptide is insulin.

16. A method for administering insulin to a patient comprising topically applying a composition comprising a crystal phosphatidylcholine carrier and insulin to skin of the patient.

17. The method of claim 16, wherein the phosphatidylcholine carrier comprises about 85% phosphatidylcholine.

18. A method according to claim 17, wherein the phosphatidylcholine carrier contains polyenylphosphatidylcholine.

19. Use of a drug in a crystal phosphatidylcholine carrier in the manufacture of a medicament for topical administration to the skin.

20. Use of a crystal phosphatidylcholine carrier and insulin in the manufacture of a medicament for topical application to the skin of a patient.

21. A composition comprising crystallized phosphatidylcholine and drug molecules entrapped within said phosphatidylcholine, substantially as herein described with reference to any one or more of the examples but excluding comparative examples.

22. A method for topically administering a macromolecular drug comprising formulating a composition containing the drug in a crystal phosphatidylcholine carrier and applying the composition to the skin, substantially as herein described with reference to any one or more of the examples but excluding comparative examples.

23. A method for administering insulin to a patient comprising topically applying a composition comprising a crystal phosphatidylcholine carrier and insulin to skin of the patient, substantially as herein described with reference to any one or more of the examples but excluding comparative examples.

24. Use of a drug in a crystal phosphatidylcholine carrier in the manufacture of a medicament for topical administration to the skin, substantially as herein described with reference to any one or more of the examples but excluding comparative examples.

25. Use of a crystal phosphatidylcholine carrier and insulin in the manufacture of a medicament for topical application to the skin of a patient, substantially as herein described with reference to any one or more of the examples but excluding comparative examples.

DATED this Day, 17th January 2006.
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