

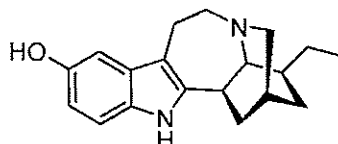
METHODS AND COMPOSITIONS FOR PREPARING NORIBOGAINE FROM VOACANGINE

Field of the Invention

- 5 [0001] This invention relates generally to methods and compositions for preparing and purifying the non-addictive alkaloid noribogaine.

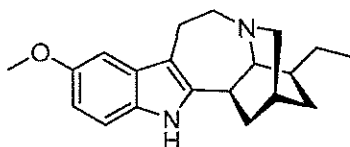
State of the Art

- [0002] Noribogaine is a well known member of the ibogaine family of alkaloids and is sometimes referred to as 12-hydroxyibogaine. US Patent No. 2,813,873 claims
10 noribogaine albeit as “12-O-demethylibogaine” while providing an incorrect structural formula for ibogaine. The structure of noribogaine has now been thoroughly evaluated and is found to combine the features of tyrtptamine, tetrahydrohavaine and indolazepines. Noribogaine can be depicted by the following formula:



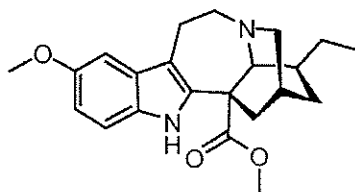
- 15 [0003] Noribogaine and its pharmaceutically acceptable salts have recently received significant attention as a non-addictive alkaloid useful in treating drug dependency (U.S. Patent No. 6,348,456) and as a potent analgesic (U.S. Patent No. 7,220,737).

[0004] Conventionally, noribogaine is prepared by demethylation of naturally occurring ibogaine:



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- which is isolated from *Tabernanth iboga*, a shrub of West Africa. Demethylation may be accomplished by conventional techniques such as by reaction with boron tribromide/methylene chloride at room temperature followed by conventional purification. Alternatively, noribogaine can be prepared from the naturally occurring
25 alkaloid, voacangine



by decarboxylation followed by demethylation as described in U.S. Patent No. 2,813,873. Such a process provides for ibogaine as the first intermediate in this two step synthesis.

[0005] Ibogaine is addictive and possesses hallucinogenic properties. It is a Schedule I-controlled substance as provided by the US Food and Drug Administration. Accordingly, methods for preparing noribogaine from ibogaine require high levels of assurance that contamination with unacceptable levels of ibogaine is avoided. As above, a one-step method for preparation of noribogaine from ibogaine via demethylation does not provide the requisite assurance that ibogaine will consistently be removed as a potential contaminant. This applies equally as well to noribogaine prepared from voacangine as described above as the penultimate compound in this synthesis is ibogaine.

[0006] Accordingly, there is an ongoing need to provide a method for preparing noribogaine from voacangine such that the potential for ibogaine contamination can be effectively and reliably minimized.

Summary of the Invention

[0007] This invention provides methods and compositions for the preparation of noribogaine wherein contamination by ibogaine is predictably and effectively minimized, if not altogether eliminated. In certain embodiments, this invention employs the use of solid supports to effect separation of noribogaine from any possible contaminants such that any ibogaine contamination is significantly reduced if not altogether eliminated. In certain embodiments, this invention employs an ion exchange resin to effect separation of noribogaine from any possible contaminants such that any ibogaine contamination is significantly reduced if not altogether eliminated.

[0008] Accordingly, in one of its method aspects, this invention is directed to a method for preparing noribogaine which method comprises:

- a) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt or ester thereof, wherein the indole nitrogen is optionally protected by an amino protecting group;

- b) optionally isolating the 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt, ester and/or amino protected derivative thereof;
- c) converting the product of step a) or b) to noribogaine; and
- d) isolating noribogaine.

5 **[0009]** In another of its method aspects, this invention is directed to a method for preparing noribogaine which method comprises:

- a) converting voacangine to 12-methoxyibogamine-18-carboxylic acid or the carboxylic acid salt or ester thereof, wherein the indole nitrogen is optionally protected by an amino protecting group;
- 10 b) optionally isolating the 12-methoxyibogamine-18-carboxylic acid or the carboxylic acid salt, ester and/or amino protected derivative thereof;
- c) converting the product of step a) or b) to noribogaine; and
- d) isolating noribogaine.

15 **[0010]** In another of its method aspects, this invention is directed to a method for preparing noribogaine which method comprises:

- a) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid the carboxylic acid salt thereof, wherein the indole nitrogen is optionally protected by an amino protecting group;
- b) converting the 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt
- 20 and/or amino protected derivative thereof to noribogaine; and
- c) isolating noribogaine.

[0011] In another of its method aspects, this invention is directed to a method for preparing and purifying noribogaine which method comprises:

- a) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid methyl ester
- 25 wherein the indole nitrogen is optionally protected by an amino protecting group;
- b) optionally covalently attaching 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof to a solid support via the hydroxyl group of 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof so as to form a suspension of solid supports having 12-hydroxyibogamine-18-
- 30 carboxylic acid methyl ester or amino protected derivative thereof bound thereto;
- c) removing residual voacangine from said suspension;
- d) cleaving and recovering the 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof from the solid support;

- e) converting the 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof to noribogaine; and
- f) isolating noribogaine.

[0012] In another of its method aspects, this invention is directed to a method for preparing and purifying noribogaine which method comprises:

- a) covalently attaching voacangine to a solid support via the indole nitrogen of voacangine so as to form a suspension of solid supports having voacangine bound thereto;
- b) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid methyl ester or 12-hydroxyibogamine-18-carboxylic acid or carboxylic acid salt thereof under conditions wherein the level of voacangine bound to the solid support is less than 0.1 weight percent;
- c) cleaving and recovering 12-hydroxyibogamine-18-carboxylic acid methyl ester or 12-hydroxyibogamine-18-carboxylic acid or carboxylic acid salt thereof from the solid support;
- d) converting the 12-hydroxyibogamine-18-carboxylic acid methyl ester or 12-hydroxyibogamine-18-carboxylic acid or carboxylic acid salt thereof to noribogaine; and
- e) purifying noribogaine.

[0013] In another of its method aspects, this invention is directed to a method for preparing and purifying noribogaine which method comprises utilizing an ion exchange resin for isolating and/or purifying the 12-hydroxyibogamine-18-carboxylic acid methyl ester, 12-hydroxyibogamine-18-carboxylic acid or carboxylic acid salt thereof, or noribogaine or a corresponding salt thereof.

[0014] In one of its composition aspects, this invention is directed to a solid support having voacangine, 12-hydroxyibogamine-18-carboxylic acid methyl ester or 12-hydroxyibogamine-18-carboxylic acid or carboxylic acid salt thereof covalently bound thereto through a cleavable linker.

Detailed Description of the Invention

[0015] This invention is directed to methods and compositions comprising noribogaine and, in particular, methods and compositions comprising highly pure noribogaine.

However, prior to describing this invention in greater detail, the following terms will first be defined.

[0016] It is to be understood that this invention is not limited to particular embodiments described, as such may, of course, vary. It is also to be understood that the terminology
5 used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0017] It must be noted that as used herein and in the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the context clearly dictates
10 otherwise. Thus, for example, reference to “a pharmaceutically acceptable excipient” includes a plurality of such excipients.

1. Definitions

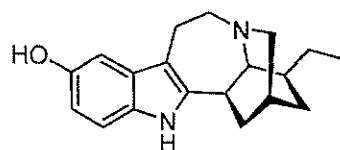
[0018] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this
15 invention belongs. As used herein the following terms have the following meanings.

[0019] As used herein, the term “comprising” or “comprises” is intended to mean that the compositions and methods include the recited elements, but not excluding others. “Consisting essentially of” when used to define compositions and methods, shall mean
20 excluding other elements of any essential significance to the combination for the stated purpose. Thus, a composition consisting essentially of the elements as defined herein would not exclude other materials or steps that do not materially affect the basic and novel characteristic(s) of the claimed invention. “Consisting of” shall mean excluding more than trace elements of other ingredients and substantial method steps. Embodiments defined by each of these transition terms are within the scope of this invention.

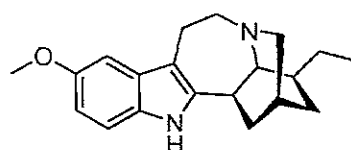
25 [0020] The term “about” when used before a numerical designation, e.g., temperature, time, amount, and concentration, including range, indicates approximations which may vary by (+) or (-) 10 %, 5 % or 1 %.

[0021] As stated above, the invention is directed to compositions comprising noribogaine and an excipient to facilitate transport across the blood brain barrier.

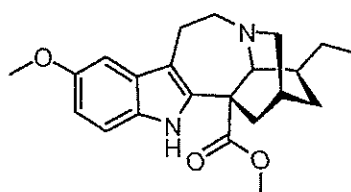
30 [0022] As used herein, the term “noribogaine” refers to the compound:



as well as its pharmaceutically acceptable salts thereof. Conventionally, noribogaine is prepared by demethylation of naturally occurring ibogaine:



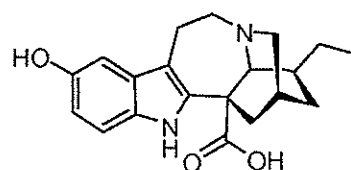
- 5 which is isolated from *Tabernanthe iboga*, a shrub of West Africa. Demethylation may be accomplished by conventional techniques such as by reaction with boron tribromide/methylene chloride at room temperature followed by conventional purification. As disclosed herein, it is contemplated that noribogaine can be prepared essentially free of any potential ibogaine contamination from voacangine:



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This invention is not limited to any particular chemical form of noribogaine and the drug may be given to patients either as a free base or as a pharmaceutically acceptable addition salt.

- 15 **[0023]** The term "12-hydroxyibogamine-18-carboxylic acid" refers to compounds of the formula:



[0024] The term "carboxylic acid salt" refers to salts of the carboxylic acid moiety of 12-hydroxyibogamine-18-carboxylic acid. Exemplary salts include, but are not limited to, the lithium, sodium, and potassium salts.

- 20 **[0025]** The term "ester" refers to esters of the carboxylic acid moiety of 12-hydroxyibogamine-18-carboxylic acid having from 1 to 12 carbon atoms. Exemplary

esters include, but are not limited to, methyl, allyl, benzyl, and aryl esters, as well as suitable substituted derivatives thereof.

[0026] The term "solid support" refers to a material having a rigid or semi-rigid surface which contain or can be derivatized to contain reactive functionality which covalently links noribogaine or ibogaine to the surface thereof through a cleavable linker. Such materials are well known in the art and include, by way of example, silica, synthetic silicates, biogenic silicates, porous glass, hydrogels, silicate-containing minerals, synthetic polymers, polystyrene, polypropylene, polyacrylamide, polyethylene glycol, polyacrylamide and copolymers thereof including copolymers of polystyrene/polyethylene glycol and polyacrylamide/polyethylene glycol, and the like.

[0027] As used herein, the term "cleavable linking arms" refer to linking arms, which are a chemical group or a covalent bond which covalently attaches at one end to a solid support and at the other end to ibogaine or noribogaine. At least one of the covalent bonds of the linking arm which attaches ibogaine or noribogaine to the solid support can be readily broken by specific chemical or enzymatic reactions, thereby providing for ibogaine or noribogaine free of the solid support. The chemical or enzymatic reactions employed to break the covalent bond of the linking arm are selected so as to be specific for bond breakage thereby preventing unintended reactions occurring elsewhere on the compound. The cleavable linking group is selected relative to ibogaine/noribogaine formed on the solid support so as to prevent premature cleavage of either ibogaine or noribogaine from the solid support as well as not to interfere with any of the procedures employed during synthesis on the support. Suitable cleavable linking arms are well known in the art, and may include such groups as carbonate groups, carbamate groups, amide groups, and the like. In a preferred embodiment, the cleavable linker arm contains no more than 10 atoms. More preferably, the cleavable linker contains from 1 to 4 carbon atoms and from 2 to 4 heteroatoms selected from oxygen, nitrogen, sulfur, S(O) and S(O)₂.

[0028] As used herein, the term "pharmaceutically acceptable salt" refers to pharmaceutically acceptable salts of noribogaine which salts are derived from a variety of organic and inorganic counter ions well known in the art and include, by way of example only, sodium, potassium, calcium, magnesium, ammonium, tetraalkylammonium, and the like; and when the molecule contains a basic functionality, salts of organic or inorganic

acids, such as hydrochloride, hydrobromide, tartrate, mesylate, acetate, maleate, oxalate and the like.

[0029] As used herein, the term "protecting group" or "Pg" refers to well known functional groups which, when bound to a functional group, render the resulting protected functional group inert to the reaction conditions to be conducted on other portions of the compound and which, at the appropriate time, can be reacted to regenerate the original functionality. The identity of the protecting group is not critical and is selected to be compatible with the remainder of the molecule. In one embodiment, the protecting group is an "amino protecting group" which protects the amino functionality of ibogaine or noribogaine during the reactions described herein. Examples of conventional amino protecting groups include, for instance, benzyl, acetyl, oxyacetyl, carboxybenzyl (Cbz), and the like. In another embodiment, the protecting group is a "hydroxy protecting group" which protects the hydroxyl functionality of noribogaine. Examples of hydroxyl protecting groups include, for instance, tosyl, benzyl, p-methoxybenzyl, p-nitrobenzyl, allyl, trityl, dialkylsilyl ethers, such as trialkylsilyl ethers such as trimethylsilyl ether, triethylsilyl ether, and t-butyldimethylsilyl ether; esters such as benzoyl, acetyl, phenylacetyl, formyl, mono-, di-, and trihaloacetyl such as chloroacetyl, dichloroacetyl, trichloroacetyl, trifluoroacetyl; and carbonates such as methyl, ethyl, 2,2,2-trichloroethyl, allyl, benzyl, and p-nitrophenyl, methoxymethyl and tosyl. Additional examples of hydroxy protecting groups may be found in standard reference works such as Greene and Wuts, *Protective Groups in Organic Synthesis*, 2d Ed., 1991, John Wiley & Sons, and McOmie *Protective Groups in Organic Chemistry*, 1975, Plenum Press.

Preparation and Purification of Noribogaine

[0030] Voacangine (12-methoxyibogamine-18-carboxylic acid methyl ester) is an alkaloid found predominantly in the rootbark of the *Voacanga africana* tree, as well as in other plants such as *Tabernanthe iboga*, *Tabernaemontana africana*, *Trachelospermum jasminoides* and *Ervatamia yunnanensis*. Voacangine has been previously used as a precursor for the semi-synthesis of ibogaine (see US Patent 2,813,873).

[0031] The present application contemplates methods for preparing noribogaine from voacangine without providing ibogaine as an intermediate. Such methods are useful for a number of reasons. First, the known methods for the preparation of noribogaine comprise demethylating ibogaine as the final step. This is unlikely to provide pure noribogaine,

and ibogaine contamination is undesirable as it is a schedule 1 controlled substance and is known to induce severe hallucinations. Second, ibogaine is isolated from the root of the *Tabernanthe iboga* and is therefore only a semi-renewable source as the plant must be compromised for isolation to take place, whereas voacangine is isolated from the bark and is thus renewable.

[0032] The compounds of this invention can be prepared using the following general methods and procedures. It will be appreciated that where typical or preferred process conditions (i.e., reaction temperatures, times, mole ratios of reactants, solvents, pressures, etc.) are given, other process conditions can also be used unless otherwise stated.

10 Optimum reaction conditions may vary with the particular reactants or solvent used, but such conditions can be determined by one skilled in the art by routine optimization procedures.

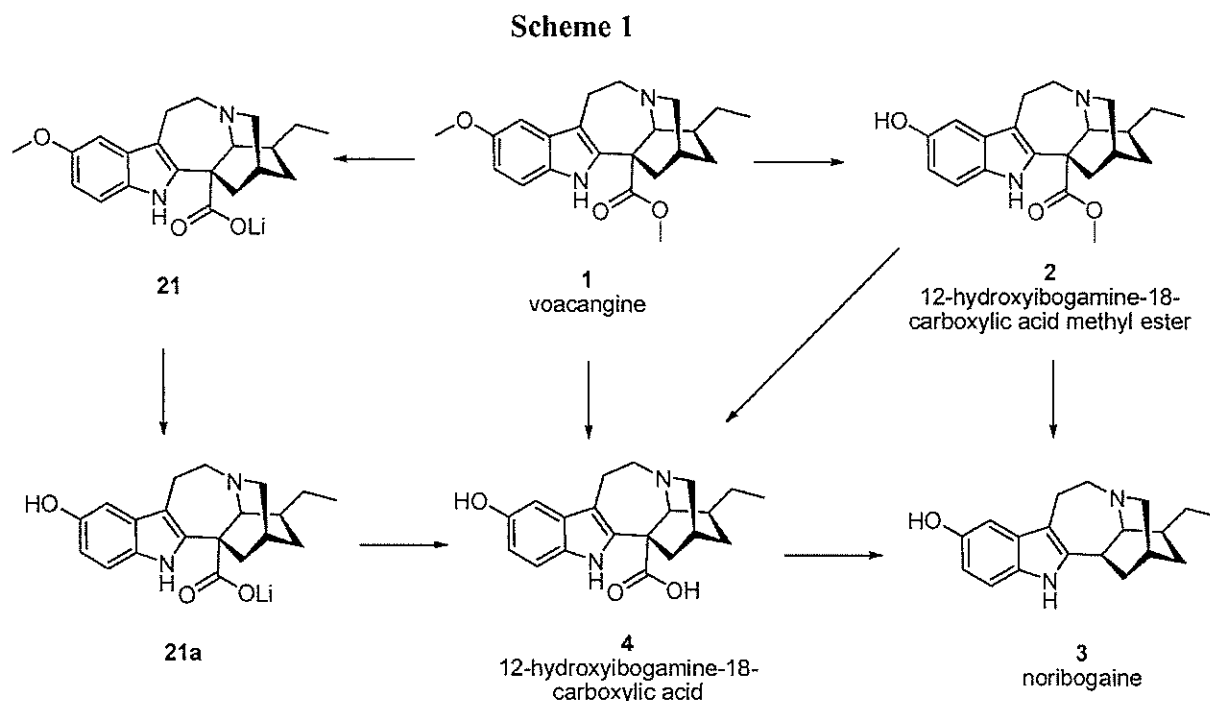
[0033] Additionally, as will be apparent to those skilled in the art, conventional protecting groups may be necessary to prevent certain functional groups from undergoing undesired reactions. Suitable protecting groups for various functional groups as well as suitable conditions for protecting and deprotecting particular functional groups are well known in the art. For example, numerous protecting groups are described in T. W. Greene and G. M. Wuts, *Protecting Groups in Organic Synthesis*, Fourth Edition, Wiley, N.Y., 2007, and references cited therein.

20 [0034] Furthermore, the compounds of this invention will typically contain one or more chiral centers. Accordingly, if desired, such compounds can be prepared or isolated as pure stereoisomers, i.e., as individual enantiomers or diastereomers, or as stereoisomer-enriched mixtures. All such stereoisomers (and enriched mixtures) are included within the scope of this invention, unless otherwise indicated. Pure stereoisomers (or enriched mixtures) may be prepared using, for example, optically active starting materials or stereoselective reagents well-known in the art. Alternatively, racemic mixtures of such compounds can be separated using, for example, chiral column chromatography, chiral resolving agents and the like.

[0035] It is contemplated that noribogaine can be prepared and/or purified from ibogaine by utilizing solid support as shown in the following Schemes, where PG represents an amine protecting group, LG represents a leaving group (e.g. a halo or alcohol), L represents a cleavable linking group (e.g. a carbonyl compound such as a

carbonate or carbamate) and the shaded circle represents a solid support. In the following Schemes, the O-demethylation of the aryl methoxy group to provide the corresponding phenol can be accomplishing using any suitable method known in the art. Suitable reagents include protic acids such as HBr and HCl, a Lewis acid (e.g. BBr₃, BCl₃, BF₃, AlCl₃, etc.), a nucleophile (e.g. RS⁻, N₃⁻, LiPPh₂, SCN⁻), NaCN at low pH (e.g. pH 12), as well as L-Selectride, NaN(SiMe₃)₂, LiN(ⁱPr)₂, SnO₂, TMSI, iodocyclohexane in refluxing DMF, and the like. In some embodiments, the O-demethylation should be performed without converting the methyl ester to the corresponding carboxylic acid and/or without affecting the linkage to the solid support. Suitable reagents can be readily ascertained by one of skill in the art and can be found, for example, in T. W. Greene and G. M. Wuts, *Protecting Groups in Organic Synthesis*, Fourth Edition, Wiley, N.Y., 2007 (see, e.g., the reactivity charts at pages 1006-1008 and 1022-1032), and references cited therein.

[0036] Noribogaine **3** can be prepared and purified from voacangine **1** by any one of the routes shown in Scheme 1.



[0037] In one embodiment, provided herein is a method for preparing noribogaine **3**, which method comprises demethylating the 12-methoxy functionality of voacangine **1** to provide the corresponding 12-hydroxyibogamine-18-carboxylic acid methyl ester **2**, or the

salt or ester thereof. In some embodiments, the indole nitrogen can be optionally protected by an amino protecting group, such as *tert*-butoxycarbonyl or *para*-methoxy benzyl. The demethylation of the 12-methoxy functionality to provide the corresponding phenol can be accomplishing using any suitable method known in the art, including, but not limited to, protic acids such as HBr and HCl, a Lewis acid (e.g. BBr₃, BCl₃, BF₃, AlCl₃, etc.), a nucleophile (e.g. LiPPh₂, RS⁻, N₃⁻, SCN⁻), NaCN at low pH (e.g. pH 12), as well as L-Selectride, NaN(SiMe₃)₂, LiN(ⁱPr)₂, SnO₂, TMSI, iodocyclohexane in refluxing DMF, and the like. Subsequent de-esterification of the methyl ester (typically under basic conditions) followed by decarboxylation provides noribogaine. These steps can be performed in the same pot, or if desired, in two separate steps to facilitate purification.

[0038] Under certain demethylation conditions, it may be the case that the methyl ester of the 12-hydroxyibogamine-18-carboxylic acid methyl ester **2** is hydrolyzed, thus forming the carboxylic acid (i.e., 12-hydroxyibogamine-18-carboxylic acid **4**). In the event that the methyl ester of **2** is hydrolyzed to give **4**, one of skill in the art could re-esterify **4** to provide the corresponding ester under conventional conditions.

Alternatively, if the methyl ester is retained one can perform traditional transesterification procedure to arrive at a specific ester. Exemplary esters include, but are not limited to, methyl, allyl, benzyl, and aryl esters, as well as suitable substituted derivatives thereof.

[0039] In the methods disclosed above, the demethylation of the 12-methoxy functionality of voacangine **1** should proceed without decarboxylation. Therefore, in certain embodiments, it may be that an acid scavenger is used. Such acid scavengers should not interfere with the demethylation reaction (e.g., they should not tie up the Lewis acid, etc.). Exemplary acid scavengers which could be used in the demethylation reaction include, but are not limited to, benzimidazole, 1,8-bis(dimethylamino)naphthalene, 1,8-bis(hexamethyltriaminophosphazeny)naphthalene, other proton sponges, and the like.

[0040] The decarboxylation reaction can be facilitated with the use of a suitable reagent under standard reaction conditions known in the art. For example, decarboxylation can be performed using a protic acid (e.g., HBr, HCl, etc.), under radical conditions via the Barton ester using, e.g., tributyltin hydride or *tert*-butylmercaptan, optionally in the presence of a suitable radical trapping agent, or other methods such as the Hunsdiecker reaction using bromine via the silver(I) salt of the carboxylic acid. Other suitable methods will be apparent to one of skill in the art.

[0041] In some embodiments, the methyl ester and the 12-methoxy functionality of voacangine can be simultaneously demethylated to provide 12-hydroxyibogamine-18-carboxylic acid **4** in one step, and then subsequently decarboxylating the 12-hydroxyibogamine-18-carboxylic acid to provide noribogaine.

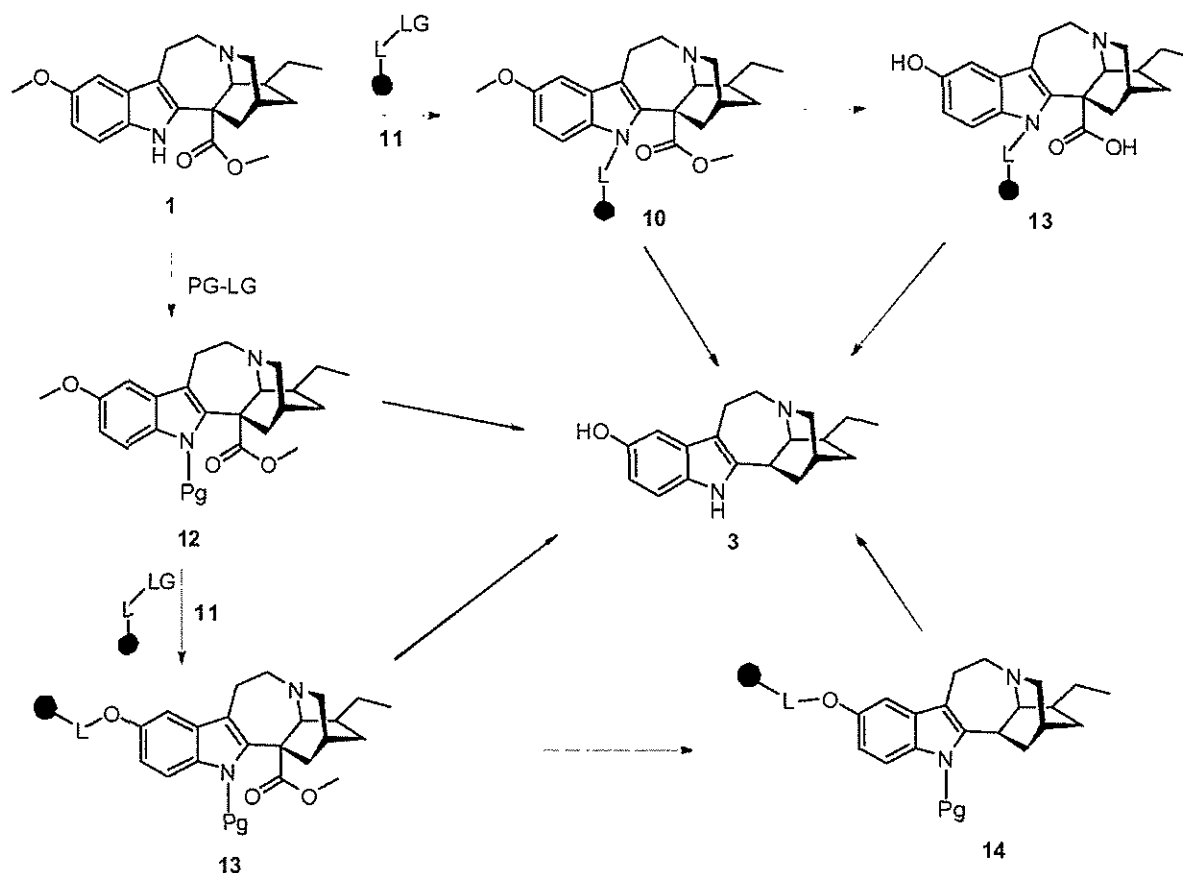
5 [0042] In some embodiments, the lithium salt of voacangine (**21**) can be prepared by treating voacangine (**1**) with n-butyllithium in hexane at 0 °C with 1-propanethiol (see, Kuehne, et al. *J. Med. Chem.*, **2003**, 46, 2716-2730). The carboxylate anion and the lithium of **21** form a tight ion pair and thus compound **21** can be isolated and purified. The lithium salt of voacangine (**21**) can likewise be demethylated using, e.g., BCl₃ or
10 BBr₃ in DCM, to provide compound **21a**, which can then undergo decarboxylation under standard conditions, such as e.g., acid catalyzed decarboxylation using HBr or HCl, to provide the appropriate salt of noribogaine **3**. Both compounds **21** and **21a** can be isolated and purified as compounds *per se*. The noribogaine can be isolated as the free base or a salt thereof, such as the hydrochloride or hydrobromide salt thereof. In one
15 embodiment, the noribogaine is isolated as noribogaine hydrochloride. In another embodiment, the noribogaine is isolated as noribogaine hydrobromide. One of skill in the art could readily interchange the anion using conventional methods.

Purification

[0043] Noribogaine **3**, as well as the various intermediates disclosed herein can be
20 further purified using standard techniques known in the art, such as column chromatography, crystallization, solid support chemistry, ion exchange chromatography, and the like.

Noribogaine **3**, as well as intermediates **2** and **4** (as prepared in Scheme 1) can be purified using solid support chemistry as shown in Scheme 2.

Scheme 2

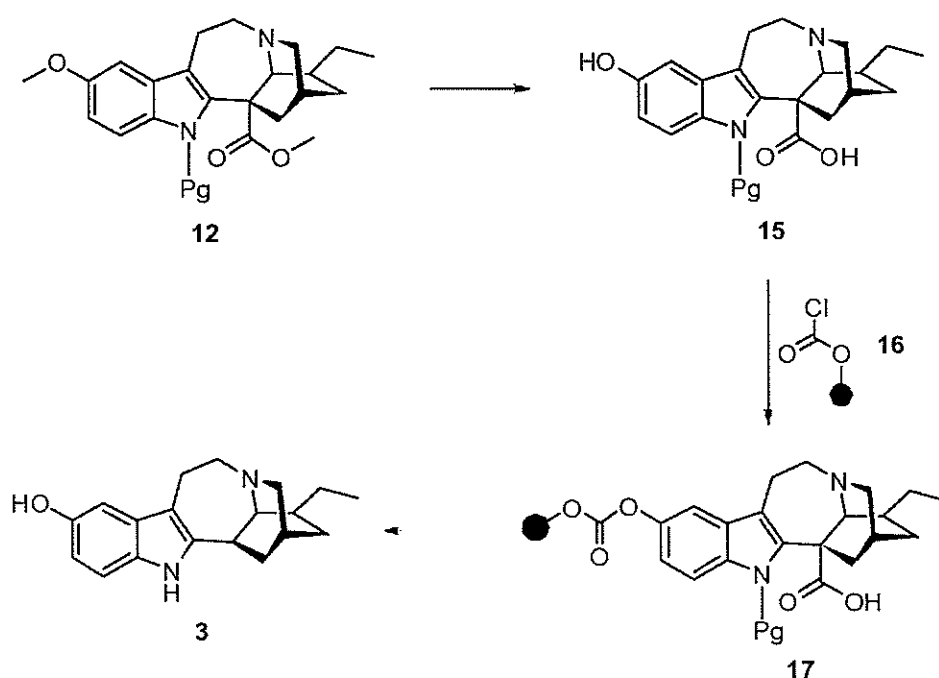


[0044] In one embodiment, the indole amine of voacangine 1 can be protected using an amine protecting group (PG-LG) to provide compound 12, followed by either tandem demethylation/decarboxylation followed by removal of the amine protecting group, or sequential demethylation (intermediates 12 and 13), followed by de-esterification and decarboxylation and removal of the amine protecting group to provide noribogaine 3. In addition, in one embodiment, noribogaine 3 can be directly prepared and purified from the demethylation/decarboxylation of voacangine 1 using methods known in the art and then purified by appending noribogaine to a solid support (compound 14), washing any contaminants, cleaving the linking group L, and recovering the noribogaine 5. In the above syntheses, one or more of the noribogaine or intermediates shown above can be purified using standard purification techniques known in the art (e.g. column chromatography, ion exchange chromatography, HPLC, and the like). Compounds of formula 11 are commercially available or can be synthesized in one or two steps from commercially available starting materials (see, e.g. commercially available resins from

Sigma-Aldrich®). In the compounds of Scheme 2, the linking group, L, contains a cleavable bond which is not susceptible to cleavage under the demethylating conditions used (c.g., BBr_3).

- [0045] In one embodiment, noribogaine can be prepared and purified using solid support chemistry known in the art starting from N-protected voacangine **12** in the manner shown in Scheme 3 below, wherein Pg is hydrogen or an amino protecting group and the shaded circle represents a solid support.

Scheme 3

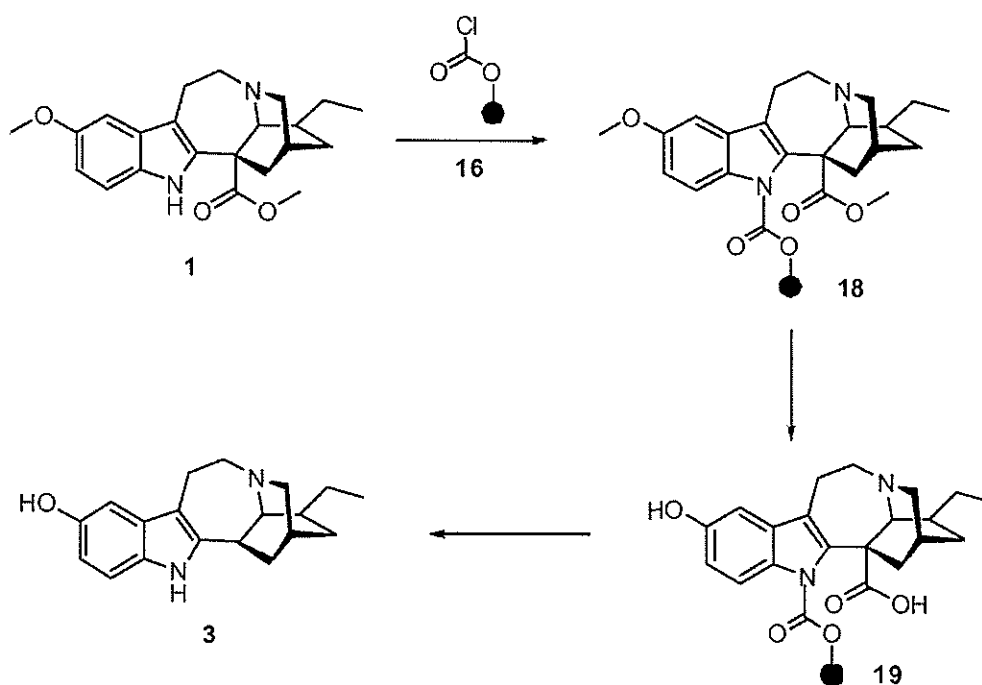


- [0046] Specifically, in Scheme 3, N-protected voacangine **12**, can be contacted with boron tribromide in methylene chloride using conditions well known in the art to provide compound **15**. Attachment of N-protected voacangine **12** to a solid support can be accomplished by use of a chloroformate/solid support, compound **16**, under conventional conditions to provide for compound **17** wherein the carbonate group is shown for illustrative purposes only as the cleavable linking group. Other cleavable linkers can likewise be used in the methods depicted in Scheme 3. As compound **12** does not contain a functional group reactive with compound **3**, only compound **15**, will react with the solid support and provide for compound **17**. Repeated washing of compound **17** will remove any unreacted compound **12** from contaminating the sample of amino protected noribogaine used in this reaction. Furthermore, at any time, a small portion of the solid

support can be removed to provide a sample of noribogaine **3** (after cleavage of the solid support and N-deprotection/decarboxylation). The sample can then be analyzed for purity by conventional methods such as GC/LCMS, HPLC, NMR, etc.

- [0047] As desired, exceptionally pure noribogaine **3** can be obtained by repeating the process of binding compound **3** to a solid support via the hydroxyl group of amino protected noribogaine and washing any contaminating voacangine from the suspension. By repeating this process as often as necessary and preferably no more than 5 times, it is contemplated that noribogaine **3** having no detectable amount of ibogaine (i.e. less than 100 ppt) can be prepared.
- 10 [0048] In another embodiment, noribogaine can be prepared and purified from voacangine **1** in the manner described in Scheme 4 below.

Scheme 4



- [0049] In Scheme 4, voacangine **1** can be bound via conventional techniques to a solid support, compound **16**, through a cleavable linker arm which, for the sake of illustration only, is depicted as a carbamate bond in resulting compound **18**. Compound **18** can then be contacted with boron tribromide in methylene chloride using conditions well known in the art to provide for compound **19**. Cleavage of the cleavable linker in compound **19** provides for noribogaine **3**.

- [0050] In one embodiment, noribogaine **3** can be purified by conventional techniques including high performance liquid chromatography (HPLC) and the purity level of the resulting purified compound confirmed by GC/LCMS. In addition, the noribogaine and any of the intermediates (i.e., either of compounds **2** or **4**) can be further purified using ion exchange chromatography. In principal, the stationary phase is an ion exchange resin that carries charged functional groups which interact with oppositely charged groups of the compound to be retained. Such methods are utilized routinely in the art to purify compounds having an ionic functional group, such as an ionized phenol. Accordingly, a solution containing **2**, **3**, or **4**, or an anion thereof, can be loaded onto a suitable cationic resin. Any residual unreacted ibogaine present can then be eluted using a suitable solvent (e.g., acetone, ethyl acetate, etc.). Once the eluent is determined to be free of ibogaine (e.g., by HPLC, LCMS, etc.), the purified **2**, **3**, or **4** can be eluted off the resin. Suitable cationic resins can be purchased from commercial sources (Aldrich®, Fisher Scientific®, etc.).
- [0051] The following synthetic and biological examples are offered to illustrate this invention and are not to be construed in any way as limiting the scope of this invention. Unless otherwise stated, all temperatures are in degrees Celsius.

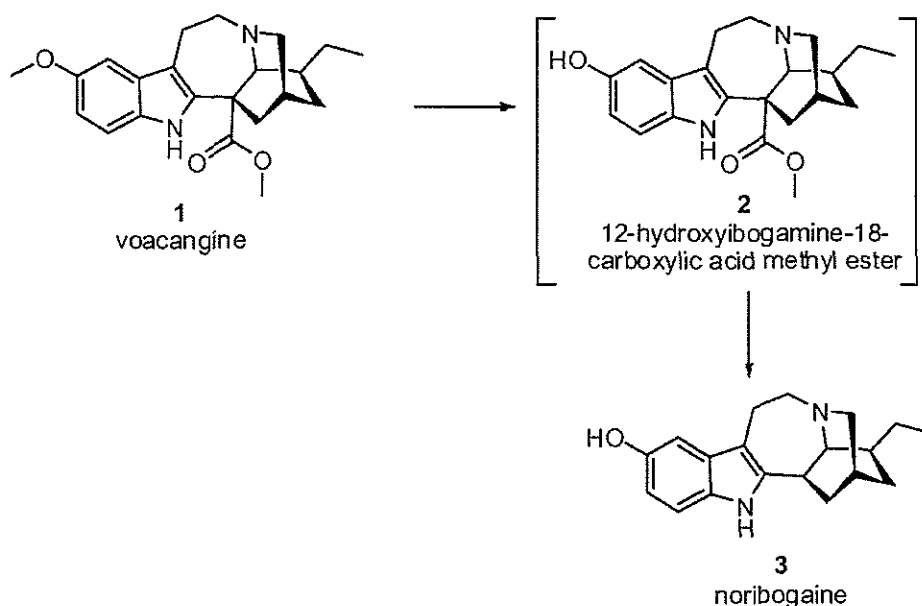
EXAMPLES

- [0052] In the examples below, the following abbreviations have the following meanings. If an abbreviation is not defined, it has its generally accepted meaning.

Example 1 – Synthesis of Noribogaine from Voacangine

[0053] Example 1 illustrates one method for the synthesis and purification of noribogaine from ibogaine which method follows Scheme 5 below.

Scheme 5



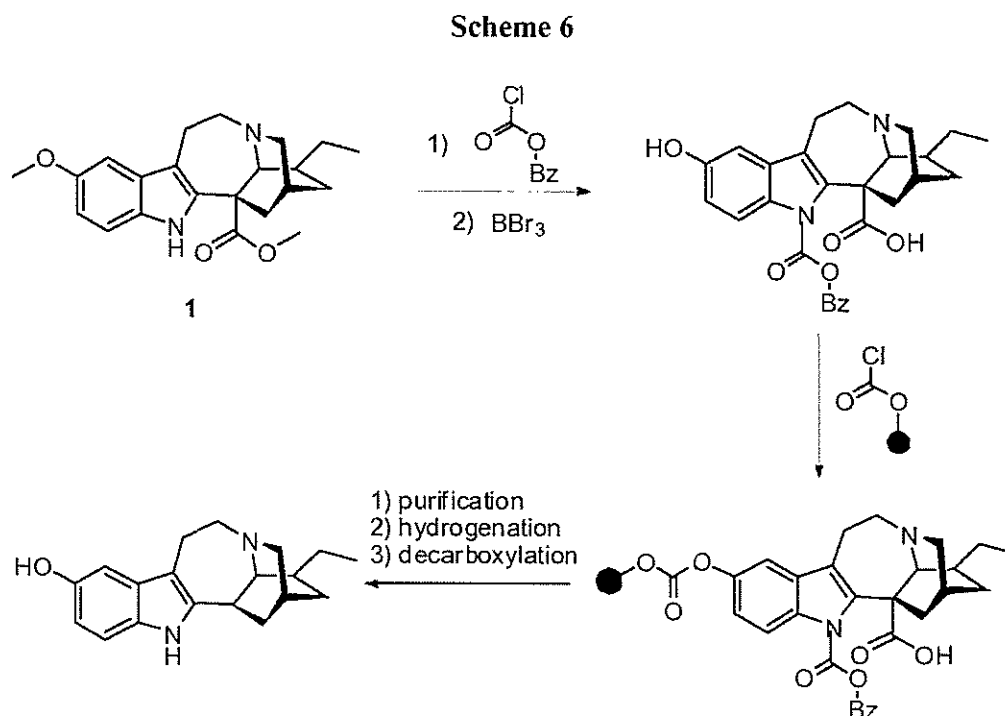
[0054] Voacangine **1** can be taken up in a dichloromethane/ethanethiol solution and cooled to 0 to -10 °C (ice salt bath). An excess (1-3 molar equivalents) of a suitable Lewis acid (boron trichloride, boron tribromide or aluminum trichloride) is added portionwise. The resultant mixture is stirred at 25 to 50 °C for 2 to 24 hours until determined to be sufficiently complete by TLC. The reaction mixture can then be diluted with fresh dichloromethane, washed with a saturated NaHCO₃ solution, dried and evaporated under reduced pressure which is contemplated to provide the corresponding 12-hydroxyibogamine-18-carboxylic acid methyl ester **2**, which may then be purified by silica gel column chromatography using a gradient of hexane and ethylacetate or used in the next step without purification.

[0055] A solution of 12-hydroxyibogamine-18-carboxylic acid methyl ester **2** as provided above in a potassium/methanol solution can be heated and held at reflux for about 6 hours, at which time the solvent can be stripped, water added and the resulting aqueous solution is washed with ether, acidified to a pH of about 2 (conc HCl), and evaporated to dryness. The residue can then be taken up in a chloroform/methanol mixture and the potassium chloride filtered off to provide the hydrochloride salt of noribogaine **1**. The free base of noribogaine can be obtained by basifying an aqueous solution of the hydrochloride salt of noribogaine **1** (e.g. with solid sodium bicarbonate, sodium carbonate, etc.) and extracting the basic aqueous solution with ether (at least 3X).

the combined ethereal fractions can be combined and evaporated to provide noribogaine 1.

Example 2 – Synthesis and Purification of Noribogaine from Voacangine using Solid Support

[0056] Example 2 illustrates one method for the synthesis and purification of noribogaine from voacangine which method follows Scheme 6 below.



- [0057] Specifically, in Scheme 6, voacangine is contacted with a stoichiometric excess of benzyl chloroformate (BzCO_2Cl) in an inert solvent such as tetrahydrofuran. The reaction mixture further contains at least a stoichiometric equivalent of diisopropylethylamine relative to voacangine so as to scavenge the acid generated during the reaction. The reaction is maintained at room temperature under an inert atmosphere until the reaction is substantially complete as evidenced by, for example, thin layer chromatography. At which time, an O-demethylating reagent (e.g. boron tribromide or aluminum trichloride), and preferably a stoichiometric excess thereof, is added to the reaction mixture which is then maintained under suitable conditions (e.g. 0°C to room temperature) wherein the aryl methoxy group of voacangine has been converted to the

corresponding hydroxyl group. It is contemplated that under these reaction conditions, the methyl ester will de-esterify to provide the corresponding acid.

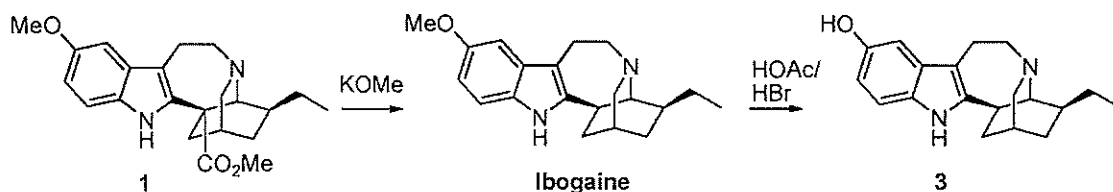
[0058] The phenol generated above is then employed as a complementary functionality for attachment of a solid support. In particular, an excess of chloroformate bound to a solid support is utilized under conventional conditions such that a cleavable carbonate bond is formed. Chloroformate bound to a solid support can be prepared from a hydroxy-bearing polymer support (e.g. hydroxymethyl)polystyrene or polymer-bound benzyl alcohol, both commercially available from Sigma-Aldrich®) and carbonyl dichloride.

[0059] In one particular example, 1kg of solid support containing CBZ protected 12-hydroxyibogamine-18-carboxylic acid is loaded onto a column. The stopper of the column is partially opened so that a flow rate through the column of 0.5 liters per hour is maintained. Methylene chloride is continuously fed to the top of the column and recovered at the base of the column. The elution of fresh solvent is continued until the effluent no longer contains either of the unreacted starting materials. At which time, a portion of the solid support is loaded into a hydrogenation vessel together with methanol and a catalytic amount of palladium on carbon. Hydrogenation is continued under elevated pressure for approximately 5 hours. The reaction is then stopped and the methanol recovered and stripped to provide 12-hydroxyibogamine-18-carboxylic acid. Decarboxylation of 12-hydroxyibogamine-18-carboxylic acid can be accomplished using a metal (i.e. potassium, copper, etc.) in refluxing methanol. Additional purification/analysis of the resultant noribogaine **3** can be provided by HPLC as desired.

Example 3 – Synthesis of Noribogaine from Voacangine via the Lithium or Sodium Salt

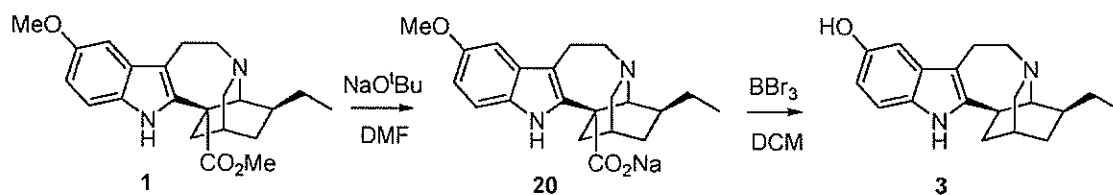
[0060] Example 3 illustrates one method for the synthesis of noribogaine from voacangine which method follows Scheme 6 below.

[0061] The conversion of voacangine **1** to Noribogaine **3** has been reported as early as 1957 (Janot and Goutarel, US 2,813,873). This was done in either a one-step process in going from voacangine (**1**) to Noribogaine (**3**) using HOAc/HBr (48%, reflux) without separation of any intermediates, or via a two-step process starting with converting voacangine (**1**) to Ibogaine (KOMe), followed by converting the ibogaine to Noribogaine (**3**) (HBr, 48% /HOAc/ reflux). This synthesis is reproducible, but we provide herein a process for **1** to **3** that does not involve the intermediacy of ibogaine.



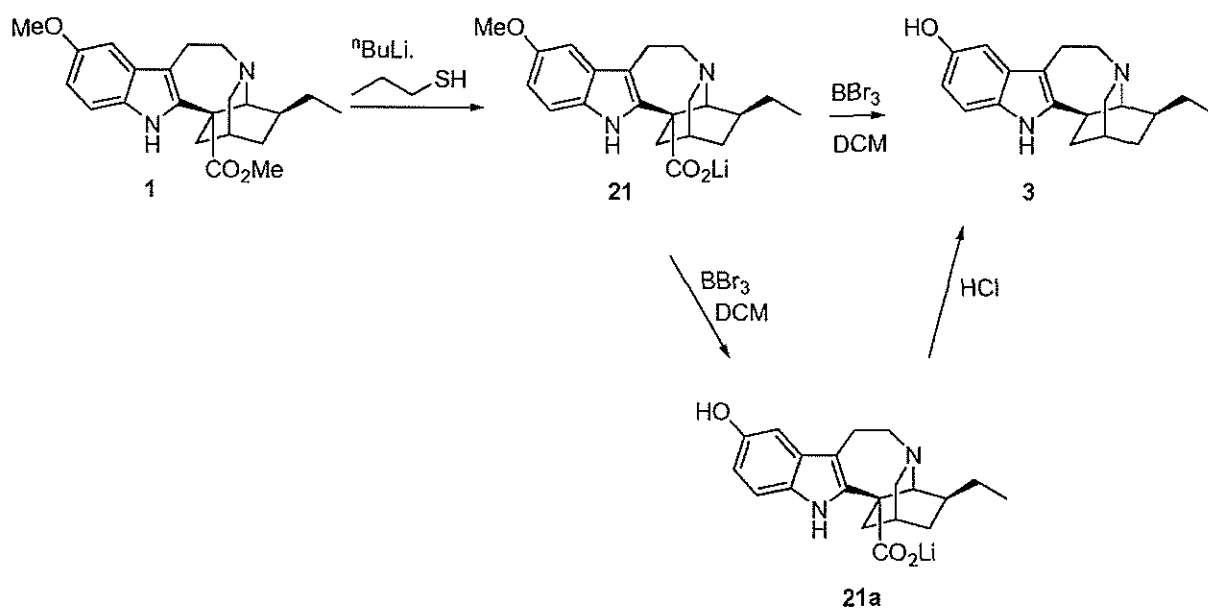
Sodium Voacanginecarboxylate Conversion to Noribogaine

[0062] Voacangine (1) can be converted to the voacanginic acid sodium salt (20) using a base, such as NaO^tBu in DMF, followed by demethylation (e.g. BBr₃ or LiPPh₂) to yield Noribogaine (3).



Lithium Voacanginecarboxylate Conversion to Noribogaine

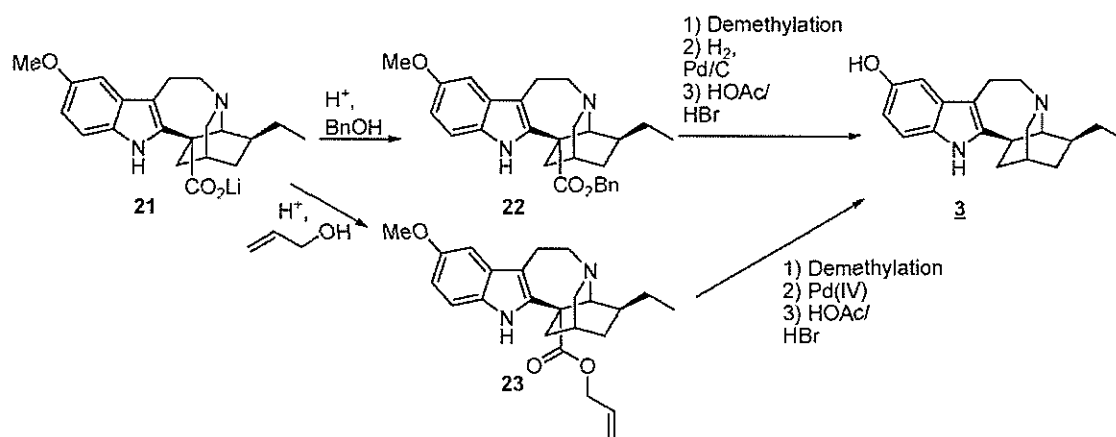
[0063] The lithium salt of voacangine (21) can be prepared by treating voacangine (1) with n-butyllithium in hexane at 0 °C with 1-propanethiol (see, Kuehne, et al. *J. Med. Chem.*, **2003**, 46, 2716-2730). The carboxylate anion and the lithium of 21 form a tight ion pair and thus compound 21 can be isolated and purified. The lithium salt of voacangine (21) can likewise be demethylated using, e.g., BCl₃ or BBr₃ in DCM, to provide compound 21a, and can then undergo decarboxylation under standard conditions, such as e.g., acid catalyzed decarboxylation using HBr or HCl, to provide noribogaine 3. Both compounds 21 and 21a can be isolated and purified as compounds *per se*. The noribogaine 3 can be isolated as the free base or a salt thereof, such as the hydrochloride or hydrobromide salt thereof. In one embodiment, the noribogaine is isolated as noribogaine hydrochloride. In another embodiment, the noribogaine is isolated as noribogaine hydrobromide. One of skill in the art could readily interchange the anion using conventional methods.



Other Approaches Under Investigation for Ibogaine-Free Production of Noribogaine

5 **[0064]** The voacanginecarboxylate salts (**20** or **21**) can be converted into other carboxyl group protected derivatives that can be demethylated and deprotected to yield Noribogaine **3**.

[0065] For example, protected derivatives include benzyl protected voacanginecarboxylate (**22**) (which can be deprotected using catalytic hydrogenation),
 10 and the allyl protected voacanginecarboxylate (**23**) (which can be deprotected with Pd(IV) , A-ring demethylation) can be utilized as intermediates.



WHAT IS CLAIMED IS:

1. A method for preparing and purifying noribogaine which method comprises:
 - a) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt or ester thereof, wherein the indole nitrogen is optionally protected by an amino protecting group;
 - b) optionally isolating the 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt, ester and/or amino protected derivative thereof;
 - c) converting the product of step a) or b) to noribogaine; and
 - d) isolating noribogaine.
2. The method of claim 1, wherein b) and c) are conducted in a one-pot synthesis.
3. The method of claim 1 or claim 2, wherein step b) further comprises the steps of b') de-esterifying the 12-hydroxyibogamine-18-carboxylic acid methyl ester to provide 12-hydroxyibogamine-18-carboxylic acid, and b'') decarboxylating the 12-hydroxyibogamine-18-carboxylic acid to provide the noribogaine.
4. A method for preparing and purifying noribogaine which method comprises:
 - a) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid wherein the indole nitrogen is optionally protected by an amino protecting group;
 - b) converting the 12-hydroxyibogamine-18-carboxylic acid to noribogaine; and
 - c) isolating noribogaine.
5. A method for preparing and purifying noribogaine which method comprises:
 - a) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid methyl ester wherein the indole nitrogen is optionally protected by an amino protecting group;
 - b) optionally covalently attaching 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof to a solid support via the hydroxyl group of 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof so as to form a suspension of solid supports having 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof bound thereto;
 - c) removing residual voacangine from said suspension;
 - d) cleaving and recovering the 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof from the solid support;

- e) converting the 12-hydroxyibogamine-18-carboxylic acid methyl ester or amino protected derivative thereof to noribogaine; and
f) isolating noribogaine.

6. The method of claim 5, wherein steps d) and e) are reversed.

5 7. The method of claim 5, wherein steps b), c) and d) are repeated up to 5 times.

8. A method for preparing and purifying noribogaine which method comprises:

- a) covalently attaching voacangine to a solid support via the indole nitrogen of voacangine so as to form a suspension of solid supports having voacangine bound thereto;

10 b) converting voacangine to 12-hydroxyibogamine-18-carboxylic acid methyl ester, 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt thereof under conditions wherein the level of voacangine bound to the solid support is less than 0.1 weight percent;

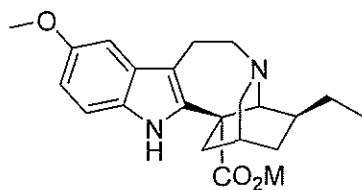
15 c) cleaving and recovering 12-hydroxyibogamine-18-carboxylic acid methyl ester, 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt thereof from the solid support;

- d) converting the 12-hydroxyibogamine-18-carboxylic acid methyl ester, 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt thereof to noribogaine; and

20 e) purifying noribogaine.

9. A solid support having voacangine, 12-hydroxyibogamine-18-carboxylic acid methyl ester, 12-hydroxyibogamine-18-carboxylic acid or the carboxylic acid salt thereof, covalently bound thereto through a cleavable linker.

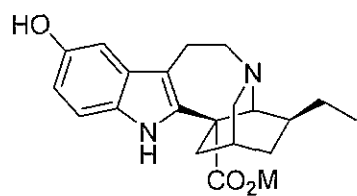
25 10. A compound of the formula:



where M is lithium, sodium or potassium.

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11. A compound of the formula:

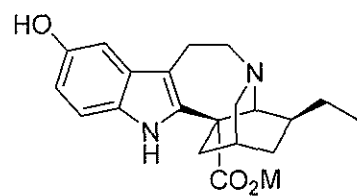


where M is lithium, sodium or potassium.

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12. The compound of claim 10 or claim 11, wherein M is lithium.

13. A compound of the formula:



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where M is lithium or sodium.