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4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol

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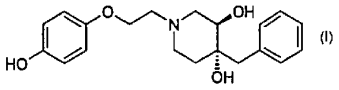
(54) Title: 4-BENZYL-1-[2-(4-HYDROXY-PHENOXY)-ETHYL]-PIPERIDINE-3,4-DIOL

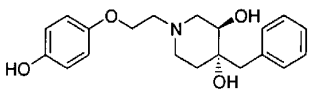


(I)

(57) Abstract: The invention relates to a compound of formula (I), its R,R- and S,S-enantiomeres and to their pharmaceutically acceptable acid addition salts. The compound of formula (I) and its R,R- and S,S-enantiomeres may be used as medicaments for the treatment of diseases, wherein the therapeutic indications include acute forms of neurodegeneration caused by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, and diseases such as schizophrenia, anxiety, depression and chronic/acute pain.

4-Benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol

The present invention relates to the compound of formula



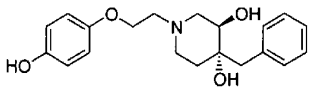
I,

to its R,R- and S,S-enantiomers and to their pharmaceutically acceptable acid addition salts.

The compounds of the present invention are NMDA (N-methyl-D-aspartate)-receptor-subtype selective blockers, which have a key function in modulating neuronal activity and plasticity which makes them key players in mediating processes underlying development of CNS including learning and memory formation and function.

Under pathological conditions of acute and chronic forms of neurodegeneration overactivation of NMDA receptors is a key event for triggering neuronal cell death. NMDA receptors are composed of members from two subunit families, namely NR-1 (8 different splice variants) and NR-2 (A to D) originating from different genes. Members from the two subunit families show a distinct distribution in different brain areas. Heteromeric combinations of NR-1 members with different NR-2 subunits result in NMDA receptors, displaying different pharmacological properties. Possible therapeutic indications for NMDA receptor subtype specific blockers include acute forms of neurodegeneration caused, e.g., by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, diseases such as schizophrenia, anxiety and depression and acute/chronic pain.

Accordingly, a first aspect of the present invention provides a compound of the formula



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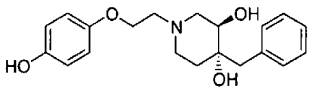
and its corresponding S,S-enantiomer and their pharmaceutically acceptable acid addition salts.

A second aspect of the present invention provides a medicament containing one or more compounds selected from the compound of formula I



I,

and its corresponding S,S-enantiomer and their pharmaceutically acceptable acid addition salts together with one or more pharmaceutically acceptable excipients.

A third aspect of the present invention provides the use of a compound of the first aspect of the present invention as described above, for the manufacture of a medicament for the treatment or prophylaxis of diseases caused by overactivation of respective NMDA receptor subtypes, which include acute forms of neurodegeneration caused by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, and diseases such as schizophrenia, anxiety, depression and acute/chronic pain.

A fourth aspect of the present invention provides a method of treating or preventing diseases which include acute forms of neurodegeneration caused by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, and, diseases such as schizophrenia, anxiety, depression and chronic/acute pain, comprising administering a compound of the first aspect of the present invention as above or of a medicament of the second aspect of the invention as described above, to a patient in need thereof.

The term "pharmaceutically acceptable acid addition salts" embraces salts with inorganic and organic acids, such as hydrochloric acid, nitric acid, sulfuric acid, lactic acid, phosphoric acid, citric acid, formic acid, fumaric acid, maleic acid, acetic acid, succinic acid, tartaric acid, methane-sulfonic acid, p-toluenesulfonic acid and the like.

4-Hydroxy-piperidin derivatives are described, for example in EP 824 098, in which the piperidine ring is substituted by one hydroxy group in 4-position. These compounds are described to possess activities on the NMDA receptor and are useful in the treatment of acute forms of neurodegeneration caused, for example, by stroke and brain trauma, and chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, ALS (amyotrophic lateral sclerosis), neurodegeneration associated with bacterial or viral infections and acute/chronic pain.

It is known from EP 824 098 that these compounds are good NMDA receptor subtype specific blockers with a high affinity for NR2B subunit containing receptors and low affinity for NR2A subunit containing receptors.

Activity versus α_1-adrenergic receptors is also low and the compounds are active *in vivo* against audiogenic seizures in mice in the low mg/kg range. Importantly, these compounds were neuroprotective in an animal stroke model, namely, a permanent occlusion of the middle cerebral artery. However, *in vitro* and *in vivo* cardiotoxicity studies showed that these compounds had the propensity to prolong cardiac action potential duration *in vitro* and consequently the "QT"-interval *in vivo* and thus, had a potential liability to produce cardiac arrhythmias. The ability of such compounds to prolong the cardiac action potential was identified as being due to an action at the hERG type potassium channel, which is important for action potential repolarisation in humans and other species, and most compounds known to prolong the QT-interval in man are active at blocking this channel. Thus, the compounds of the prior art block heterologously recombinant human ERG potassium channels.

It has now surprisingly been found that the following compounds of formula I (3R,4R) and (3S,4S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]piperidine-3,4-diol, (3R,4R)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol and (3S,4S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol.

are NMDA NR2B subtype selective antagonists whilst they share the highly specific subtype selective blocking properties of compounds of the prior art, for example of 1-[2-(4-hydroxy-phenoxy)-ethyl]-4-(4-methyl-benzyl)-piperidin-4-ol (EP 824 098), and are neuroprotectants *in vivo*, they are less active as blockers of the hERG potassium channels and, thus, are much less likely to have pro-arrhythmic activity in man.

In the following table the high selectivity of compounds of the present invention is demonstrated.

Selectivity profile of NMDA NR2B subtype selective antagonists

Compound	Inhibition of [3H]-Ro 25-6981 binding IC_{50} (μM)[a]	Inhibition of [3H]-Prazosin binding IC_{50} (μM)[b]	Inhibition of hERG K+ current IC_{50}(μM) (effect (%) at 10 μM[c])
EP 824098 1-[2-(4-hydroxy-phenoxy)-ethyl]-4-(4-methyl-benzyl)-piperidin-4-ol	0.010	3.5	0.69 μM
I (racemate)	0.045	27	>10 μM (45%)
I-1 (R,R)	0.038	25	>10 μM (44%)
I-2 (S,S)	0.039	30	>10 μM (40%)

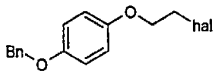
[a] Inhibition of [3H]-Ro 25-6981 binding indicates affinity for NMDA NR2B subunit containing receptors.

[b] Inhibition of [3H]-Prazosin binding indicates affinity for α_1-adrenergic receptors.

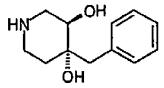
[c] Indicates potency for blockade of recombinant human ERG potassium channels expressed in a mammalian cell line (chinese hamster ovary cells, CHO).

The novel compounds of formula I and their pharmaceutically acceptable salts can be prepared by methods known in the art, for example by a process described below, which process comprises

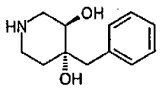
reacting a compound of formula



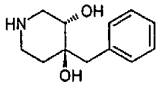
with a compound of formula



VIII (rac) or

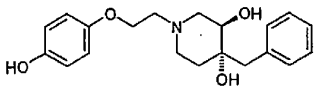


XI (R,R) or

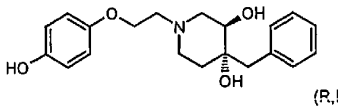


XV (S,S)

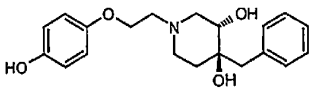
and deprotecting the hydroxy group to give compounds of formulae



(rac) I



(R,R) I-1



(S,S) I-2

and, if desired,

converting the compounds obtained into a pharmaceutically acceptable acid addition salts.

In accordance with the described process variant, 4-benzyl-3,4-dihydroxy-piperidine, (3R,4R)-4-benzyl-3,4-dihydroxy-piperidine or (3S,4S)-4-benzyl-3,4-dihydroxy-piperidine

is treated with 1-benzyloxy-4-(2-chloro-ethoxy)-benzene in the presence of K_2CO_3. The reaction is carried out at about 80 – 100 °C. The O-protecting group is then cleaved off in conventional manner, for example by hydrogenating in the presence of Pd/C.

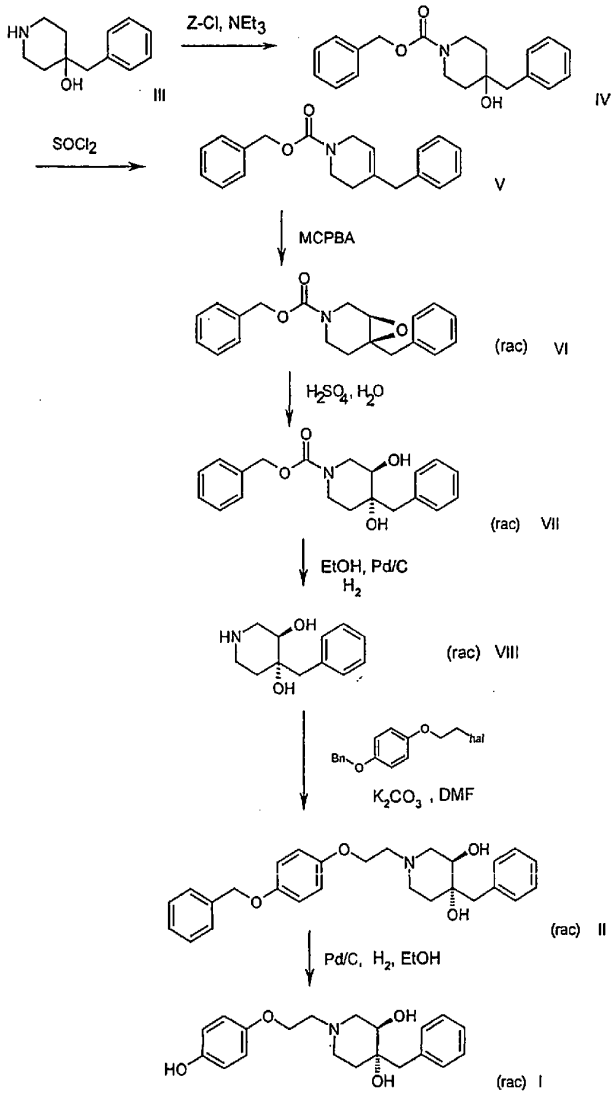
The acid addition salts of the compounds of formula I are especially well suited for a pharmaceutical use.

The following schemes 1 and 2 describe the preparation of the compound of formula I and its desired enantiomeric forms. The starting materials of formulae III and 1-benzyloxy-4-(2-chloro-ethoxy)-benzene are known compounds or can be prepared by methods known in the art.

In schemes 1 and 2 the following abbreviations have been used:

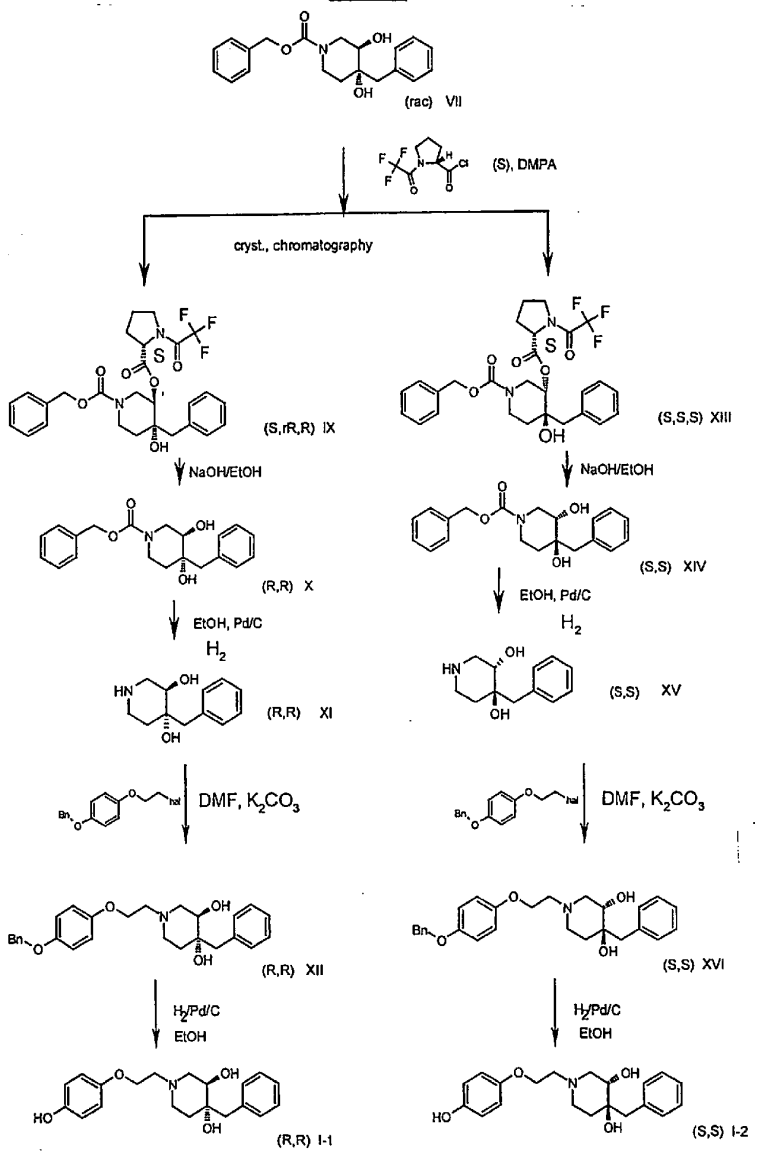
Z-Cl	benzylchloroformate
MCPBA	meta-chloroperbenzoic acid
DMAP	dimethylaminopyridine
Pd/C	palladium on carbon catalyst
DMF	dimethylformamide
Bn	benzyl

Scheme 1



wherein "hal" may be chloro or bromo.

Scheme 2


(rac) VII
(S), DMPA
cryst., chromatography
(S,rR,R) IX
(S,S,S) XIII
NaOH/EtOH
NaOH/EtOH
(R,R) X
(S,S) XIV
EtOH, Pd/C
H2
EtOH, Pd/C
H2
(R,R) XI
(S,S) XV
DMF, K2CO3
DMF, K2CO3
(R,R) XII
(S,S) XVI
H2/Pd/C
EtOH
H2/Pd/C
EtOH
(R,R) I-1
(S,S) I-2

The detailed description of the above mentioned processes is described in Examples 1 - 17.

As mentioned earlier, the compounds of formula I and their pharmaceutically acceptable addition salts possess valuable pharmacodynamic properties. They are NMDA-receptor subtype selective blockers, which have a key function in modulating neuronal activity and plasticity which makes them key players in mediating processes underlying development of CNS as well as learning and memory formation.

The compounds were investigated in accordance with the test given hereinafter.

Method 1

3H-Ro 25-6981 binding (Ro 25-6981 is [R-(R*,S*)]-α-(4-Hydroxy-phenyl)-β-methyl-4-(phenyl-methyl)-1-piperidine propanol)

Male Füllinsdorf albino rats weighing between 150-200 g were used. Membranes were prepared by homogenization of the whole brain minus cerebellum and medulla oblongata with a Polytron (10.000 rpm, 30 seconds), in 25 volumes of a cold Tris-HCl 50 mM, EDTA 10 mM, pH 7.1 buffer. The homogenate was centrifuged at 48.000 g for 10 minutes at 4 °C. The pellet was resuspended using the Polytron in the same volume of buffer and the homogenate was incubated at 37 °C for 10 minutes. After centrifugation the pellet was homogenized in the same buffer and frozen at –80 °C for at least 16 hours but not more than 10 days. For the binding assay the homogenate was thawed at 37 °C, centrifuged and the pellet was washed three times as above in a Tris-HCl 5 mM, pH 7.4 cold buffer. The final pellet was resuspended in the same buffer and used at a final concentration of 200 µg of protein/ml.

3H-Ro 25-6981 binding experiments were performed using a Tris-HCl 50 mM, pH 7.4 buffer. For displacement experiments 5 nM of 3H-Ro 25-6981 were used and non specific binding was measured using 10 µM of tetrahydroisoquinoline and usually it accounts for 10% of the total. The incubation time was 2 hours at 4 °C and the assay was stopped by filtration on Whatmann GF/B glass fiber filters (Unifilter-96, Packard, Zürich, Switzerland). The filters were washed 5 times with cold buffer. The radioactivity on the filter was counted on a Packard Top-count microplate scintillation counter after addition of 40 mL of microscint 40 (Canberra Packard S.A., Zürich, Switzerland).

The effects of compounds were measured using a minimum of 8 concentrations and repeated at least once. The pooled normalized values were analyzed using a non-linear

regression calculation program which provide IC_{50} with their relative upper and lower 95% confidence limits (RS1, BBN, USA).

Method 2

3H-Prazosin binding

Male Füllinsdorf albino rats weighing between 150-200 g were used. Membranes were prepared by homogenization of the whole brain minus cerebellum and medulla oblongata with a Plytron (10.000 rpm, 30 seconds), in 25 volumes of a cold Tris-HCl 50 mM, EDTA 10 mM, pH 7.1 buffer. The homogenate was centrifuged at 48.000 g for 10 minutes at 4 °C. The pellet was resuspended using the Polytron in the same volume of buffer and the homogenate was incubated at 37 °C for 10 minutes. After centrifugation the pellet was homogenized in the same buffer and frozen at –80 °C for at least 16 hours but not more than 10 days. For the binding assay the homogenate was thawed at 37 °C, centrifuged and the pellet was washed three times as above in a Tris-HCl 5mM, pH 7.4 cold buffer. The final pellet was resuspended in the same buffer and used at a final concentration of 200 mg of protein/ml.

3H-Prazosin binding experiments were performed using a Tris-HCl 50 mM, pH 7.4 buffer. For displacement experiments 0.2 nM of 3H-Prazosine were used and non specific binding was measured using 100 mM of Chlorpromazine. The incubation time was 30 minutes at room temperature and the assay was stopped by filtration on Whatman GF/B glass fiber filters (Unifilter-96, Canberra Packard S.A., Zürich, Switzerland). The filters were washed 5 times with cold buffer. The radioactivity on the filter was counted on a Packard Top-count microplate scintillation counter after addition of 40 ml of microscint 40 (Canberra Packard S.A., Zürich, Switzerland). The effects of compounds were measured using a minimum of 8 concentrations and repeated at least once. The pooled normalized values were analyzed using a non-linear regression calculation program which provide IC_{50} with their relative upper and lower 95% confidence limits (RS1, BBN, USA).

The thus-determined activity of compounds in accordance with the invention is in the range of 0.039– 0.045 (in μM), as described in the table above.

Method 3

Methods for studying the inhibition of the hERG K^+ channel.

CHO cells were stably transfected by a pcDNA3-hERG expression vector containing a SV40-neo cassette for selection. Cells were thinly plated into 35 mm dishes and used for the electrophysiological experiment ½-3 d later.

During the experiment the cells were continuously superfused with an extracellular saline containing (in mM): NaCl 150, KCl 10, $MgCl_2$ 1, $CaCl_2$ 3, HEPES 10 (pH = 7.3 by addition of NaOH). A 10-mM stock solution of the test compound was made from pure DMSO. Test solution were made by at least 1000-fold dilution of the stock solution into the extracellular saline. The glass micropipettes for whole-cell patch-clamp recording were filled with a containing (in mM): KCl 110, BAPTA 10, HEPES 10, $MgCl_2$ 4.5, Na_2ATP 4, Na_2-phosphocreatine 20, creatine kinase 200 µg/ml (pH = 7.3 by addition of KOH).

The whole-cell configuration of the patch-clamp technique was used for the experiments. Cells were clamped to –80 mV holding potential and repetitively (0.1 Hz) stimulated by a voltage pulse pattern consisting of a 1-s conditioning depolarisation to 20 mV immediately followed by a hyperpolarisation of 50 ms duration to –120 mV. The membrane current was recorded for at least 3 min (18 stimuli) before compound application (control), and then for another two 3-min intervals in presence of two different concentrations of the compound. The current amplitudes (I_{test}) at the end of each compound application interval were divided by the mean current amplitude ($I_{control}$) during the initial control period to calculate the percentage effect of the compound:

effect (%) = $(1-I_{test}/I_{control}) \cdot 100$.

Compound concentrations were chosen in decade steps (usually 1 and 10 µM) around the expected 50 % inhibitory concentration (IC_{50}). If after the first experiment the IC_{50} turned out to lie outside the range between the two chosen concentrations the concentrations were changed to bracket the IC_{50} in the following experiments. The compound was tested on at least three cells. Its IC_{50} was then estimated from the population of all percent-effect values by non-linear regression using the function

effect = $100 / (1 - IC_{50} / \text{concentration})^{Hill}$).

Concentrations higher than 10 µM were not tested. If 10 µM of the compound turned out to produce less than 50 % effect, IC50 was labelled as ">10 µM" and the compound was characterised by the average effect seen at 10 µM.

The compounds of formula I and their salts, as herein described, together with pharmaceutically inert excipients can be incorporated into standard pharmaceutical dosage forms, for example, for oral or parenteral application with the usual pharmaceutical adjuvant materials, for example, organic or inorganic inert carrier materials, such as, water, gelatin, lactose, starch, magnesium stearate, talc, vegetable oils, gums, polyalkylene-glycols and the like. Examples of pharmaceutical preparations in solid form are tablets, suppositories, capsules, or in liquid form are solutions, suspensions or emulsions.

Pharmaceutical adjuvant materials include preservatives, stabilizers, wetting or emulsifying agents, salts to change the osmotic pressure or to act as buffers. The pharmaceutical preparations can also contain other therapeutically active substances.

The daily dose of compounds of formula I to be administered varies with the particular compound employed, the chosen route of administration and the recipient. Representative of a method for administering the compounds of formula I is by the oral and parenteral type administration route. An oral formulation of a compound of formula I is preferably administered to an adult at a dose in the range of 1 mg to 1000 mg per day. A parenteral formulation of a compound of formula I is preferably administered to an adult at a dose in the range of from 5 to 500 mg per day.

The invention is further illustrated in the following examples.

Example 1

4-Benzyl-4-hydroxy-piperidine-1-carboxylic acid benzyl ester

To a solution of 5.0 g (26.2 mmol) of 4-hydroxybenzylpiperidine in 50 ml CH_2Cl_2 were added under argon 5.5 ml (39.3 mmol) of Et_3N and 3.7 ml (26.2 mmol) of benzylchloroformate at 0 °C. After stirring the reaction mixture for 3 hours at r.t. 100 ml 1N HCl were added and the aqueous phase was extracted twice with CH_2Cl_2 and the combined organic layers were washed with 50 ml water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give the crude product. Purification by chromatography over silica gel (hexane/ethyl acetate 4:1 to 2:1) yielded 3.9 g 4-benzyl-4-hydroxy-piperidine-1-carboxylic acid benzyl ester (11.9 mmol, 48 %) as a yellow oil.
MS: m/e = 326 (M+1)

Example 2

4-Benzyl-3,6-dihydro-2H-pyridine-1-carboxylic acid benzyl ester

To a solution of 40.0 g (123 mmol) of 4-benzyl-4-hydroxy-piperidine-1-carboxylic acid benzyl ester in 250 ml CH_2Cl_2 were added 39.6 ml (492 mmol) pyridine and at 0 °C 17.8 ml (246 mmol) of $SOCl_2$. The reaction mixture was stirred for 30 min. at 0 °C and then 250 ml of aqueous (2N) HCl were added. The aqueous phase was extracted twice with CH_2Cl_2 and the combined organic layers were washed with water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 36.3 g (118 mmol, 96%) of 4-benzyl-3,6-dihydro-2H-pyridine-1-carboxylic acid benzyl ester as an orange oil.
MS: m/e = 308 (M+1)

Example 3

(1R,6S) and (1S,6R)-6-Benzyl-7-oxa-3-aza-bicyclo[4.1.0]heptane-3-carboxylic acid benzyl ester

To a solution of 36.0 g (117 mmol) of 4-benzyl-3,6-dihydro-2H-pyridine-1-carboxylic acid benzyl ester in 250 ml CH_2Cl_2 were added 40.9 g (166 mmol, ~ 70 %) MCPBA. The reaction mixture was stirred for 2 hours and a 1N NaOH-solution was added. The aqueous phase was extracted twice with CH_2Cl_2 and the combined organic layers were washed with 1 N NaOH, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 37.6 g (116 mmol, 99 %) of (1R,6S) and (1S,6R)-6-benzyl-7-oxa-3-aza-bicyclo[4.1.0]heptane-3-carboxylic acid benzyl ester as an oil.
MS: m/e = 324 (M+1)

Example 4

(3R,4R) and (3S,4S)-4-Benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester

To a solution of 37.6 g (116 mmol) of (1R,6S) and (1S,6R)-6-benzyl-7-oxa-3-aza-bicyclo[4.1.0]heptane-3-carboxylic acid benzyl ester in 170 ml THF were added 37 ml H_2SO_4 (10 %). The reaction mixture was stirred for 16 hours and then concentrated under reduced pressure. The residue was dissolved in ethyl acetate and extracted with sat. $NaHCO_3$. The aqueous phase was extracted twice with ethyl acetate and the combined organic layers were washed with sat. $NaHCO_3$, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 40.8 g (100 %, purity ~ 95 %) of crude (3R,4R) and (3S,4S)-4-benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester.
MS: m/e = 342 (M+1)

Example 5

(4*R*, 4*R*), 4-Benzyl-4-hydroxy-3-((2*S*)-trifluoroacetyl-cyclopentanecarbonyloxy)-piperidine-1-carboxylic acid benzyl ester

To a solution of 43.0 g (126 mmol) (3R,4R) and (3S,4S)-4-benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester and 23.1 g (189 mmol) DMAP in 600 ml CH_2Cl_2 were added dropwise under argon 500 ml (340 mmol, 0.70 N) (S)-N-trifluoroacetyl-prolinechloride. The reaction mixture was stirred for 16 hours at r.t. and then sat. $NaHCO_3$ solution was added. The aqueous phase was extracted three times with CH_2Cl_2 and the combined organic layers were washed with sat. $NaHCO_3$ and 1N HCl, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give the crude product. Purification by chromatography on silica gel (hexane : ethyl acetate 4:1 to 1 : 1) and crystallization from diethylether yielded 17.9 g (33 mmol, 27 %) (3*R*,4*R*), 4-benzyl-4-

hydroxy-3-(2S)-trifluoroacetyl-cyclopentanecarbonyloxy)-piperidine-1-carboxylic acid benzyl ester.

MS: m/e = 535 (M+1), (c = 1.11, CH_2Cl_2).

Example 6

(3S,4S), 4-Benzyl-4-hydroxy-3-((2S)-trifluoroacetyl-cyclopentanecarbonyloxy)-piperidine-1-carboxylic acid benzyl ester

To a solution of 43.0 g (126 mmol) (3R,4R) and (3S,4S)-4-benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester and 23.1 g (189 mmol) DMAP in 600 ml CH_2Cl_2 were added under argon 500 ml (340 mmol, 0.70 N) (S)-N-trifluoroacetyl-prolinechloride dropwise. The reaction mixture was stirred for 16 hours at r.t. and then sat. $NaHCO_3$ solution was added. The aqueous phase was extracted three times with CH_2Cl_2 and the combined organic layers were washed with sat. $NaHCO_3$ and 1N HCl, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give the crude product. Purification by chromatography on silica gel (hexane : ethyl acetate 4:1 to 1 : 1) and crystallization from diethylether yielded 14.3 g (27 mmol, 21 %) (3S,4S)-4-benzyl-4-hydroxy-3-((2S)-trifluoroacetyl-cyclopentanecarbonyloxy)-piperidine-1-carboxylic acid benzyl ester.

MS: m/e = 535 (M+1), (c = 1.11, CH_2Cl_2).

Example 7

(3R,4R)-4-Benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester

To a solution of 17.9 g (33.5 mmol) (3*R*), (4*R*), 4-benzyl-4-hydroxy-3-((2S)-trifluoroacetyl-cyclopentanecarbonyloxy)-piperidine-1-carboxylic acid benzyl ester in 500 ml EtOH were added 250 ml (250 mmol) of 1 N NaOH. The reaction mixture was stirred for 16 hours and water was then added. The aqueous phase was extracted three times with CH_2Cl_2 and the combined organic layers were washed with water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 11.2 g (32.8 mmol, 98 %) *(3R,4R)*-4-benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester as an oil.

MS: m/e = 342.3 (M+1), $[\alpha]_D^{20}$ = -36.75 (c = 1.02, CH_2Cl_2).

Example 8

(3S,4S)-4-Benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester

To a solution of 14.3 g (27 mmol) (3*S*,4*S*)-4-benzyl-4-hydroxy-3-((2S)-trifluoroacetyl-cyclopentanecarbonyloxy)-piperidine-1-carboxylic acid benzyl ester in 500 ml EtOH were added 250 ml (250 mmol) 1 N NaOH. The reaction mixture was stirred for

16 hours and water was added. The aqueous phase was extracted three times with CH_2Cl_2 and the combined organic layers were washed with water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 8.4 g (25 mmol, 92 %) *(3S,4S)*-4-benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester as an oil.

MS: m/e = 342.3 (M+1), $[\alpha]_D^{20} = 35.30$ (c = 1.02, CH_2Cl_2).

Example 9

(3R,4R) and (3S,4S)-4-Benzyl-3,4-dihydroxy-piperidine

(3R,4R) and (3S,4S)-4-Benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester 1.46 g (4.3 mmol) was dissolved in 30 ml EtOH and hydrogenated in the presence of 400 mg Pd/C (10%) under atmospheric pressure of H_2 at r.t. After 16 hours the reaction was complete and the catalyst was filtered off and the solvent was removed under reduced pressure to give 796 mg (3.8 mmol, 89 %) (3R,4R) and (3S,4S)-4-benzyl-3,4-dihydroxy-piperidine as an oil.

MS: m/e = 207.1 (M).

Example 10

(3R,4R)-4-Benzyl-3,4-dihydroxy-piperidine

(3R,4R)-4-benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester 11.0 g (32 mmol) was dissolved in 250 ml EtOH and hydrogenated in the presence of 1.1 g Pd/C (10%) under atmospheric pressure of H_2 at r.t. After 16 hours the reaction was complete and the catalyst was filtered off and the solvent was removed under reduced pressure to give 6.6 g (32 mmol, 100 %) *(3R,4R)*-4-benzyl-3,4-dihydroxy-piperidine as an oil.

MS: m/e = 207.1 (M), $[\alpha]_D^{20} = -42.3$ (c = 1.00, ethanol).

Example 11

(3S), (4S)-4-Benzyl-3,4-dihydroxy-piperidine

(3S,4S)-4-Benzyl-3,4-dihydroxy-piperidine-1-carboxylic acid benzyl ester 8.2 g (24 mmol) was dissolved in 250 ml EtOH and hydrogenated in the presence of 1.1 g Pd/C (10%)under atmospheric pressure at r.t. After 16 hours the reaction was complete and the catalyst was filtered off and the solvent was removed under reduced pressure to give 5.5 g (quant., ~95 % purity) *(3S,4S)*-4-Benzyl-3,4-dihydroxy-piperidine as an oil.

MS: m/e = 207.1 (M), $[\alpha]_D^{20} = +42.57$ (c = 1.05, ethanol).

Example 12

(3R,4R) and (3S,4S)-4-Benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol

To a solution of 0.2 g (1.0 mmol) (3R,4R) and (3S,4S)- 4-benzyl-3,4-dihydroxy-piperidine in 10 ml DMF were added 297 mg (1.0 mmol) 1-benzyloxy-4-(2-chloro-ethoxy)-benzene and 0.2 g (1.5 mmol) K_2CO_3 and the reaction mixture was heated to 90 °C for 16 hours. After the addition of water, the aqueous phase was extracted three times with ethyl acetate and the combined organic layers were washed with water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 551 mg (100 %, ~ 80 % purity) (3R,4R) and (3S,4S)-4-benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol as a solid.

MS: m/e = 434.5 (M+1).

Example 13

(3R,4R)-4-Benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol

To a solution of 5.0 g (24 mmol) *(3R,4R)*-4-benzyl-3,4-dihydroxy-piperidine in 150 ml DMF were added 7.4 g (24 mmol) 1-benzyloxy-4-(2-chloro-ethoxy)-benzene and 5.0 g (36 mmol) K_2CO_3 and the reaction mixture was heated to 90 °C for 72 hours. After the addition of water the aqueous phase was extracted three times with ethyl acetate and the combined organic layers were washed with water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 10.5 g (24 mmol, 100 %) *(3R,4R)*-4-benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol as a solid.

MS: m/e = 434.5 (M+1), $[\alpha]_D^{20}$ = - 27.5 (c = 0.95, CH_2Cl_2).

Example 14

(3S,4S)-4-Benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol

To a solution of 5.0 g (24 mmol) *(3S,4S)*-4-benzyl-3,4-dihydroxy-piperidine in 150 ml DMF were added 7.4 g (24 mmol) 1-benzyloxy-4-(2-chloro-ethoxy)-benzene and 5.0 g (36 mmol) K_2CO_3 and the reaction mixture was heated to 90 °C for 72 hours. After the addition of water the aqueous phase was extracted three times with ethyl acetate and the combined organic layers were washed with water, dried over $MgSO_4$ and the solvent was removed under reduced pressure to give 10.9 g (quant., ~ 95 % purity) *(3S,4S)*-4-benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol as a solid.

MS: m/e = 434.5 (M+1), $[\alpha]_D^{20}$ = +26.2 (c = 1.04, CH_2Cl_2).

Example 15

(3R,4R) and (3S,4S)-4-Benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol

(3R,4R) and (3S,4S)-4-benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol 550 mg (1.3 mmol) was dissolved in 10 ml EtOH and hydrogenated in the presence of 100 mg Pd/C (10 %) under atmospheric pressure at 50 °C. After 4 hours the reaction was complete and the catalyst was filtered off and the solvent was removed under reduced pressure to give the crude product. Purification by chromatography (CH_2Cl_2/MeOH 9:1) yielded 249 mg (0.73 mmol, 56 %) (3R,4R) and (3S,4S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol as a solid.

MS: m/e = 344.4 (M+1).

Example 16

(3R,4R)-4-Benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol

(3R,4R)-4-benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol 10.3 g (24 mmol) was dissolved in 300 ml EtOH and hydrogenated in the presence of 1.1 g Pd/C (10 %) under atmospheric pressure at 50 °C. After 4 hours the reaction was complete and the catalyst was filtered off and the solvent was removed under reduced pressure to give the crude product. Purification by chromatography (CH_2Cl_2/MeOH 10:1) and crystallization from ethyl acetate and hexane yielded then 4.6 g (10.6 mmol, 45%) *(3R,4R)*-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol as a solid.

MS: m/e = 344.4 (M+1), $[\alpha]_D^{20}$ = - 36.2 (c = 1.03, CH_2Cl_2).

Example 17

(3S,4S)-4-Benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol

(3S,4S)-4-Benzyl-1-[2-(4-benzyloxy-phenoxy)-ethyl]-piperidine-3,4-diol 10.3 g (24 mmol) was dissolved in 300 ml EtOH and hydrogenated in the presence of 1.1 g Pd/C (10 %) under atmospheric pressure at 50 °C. After 4 hours the reaction was complete and the catalyst was filtered off and the solvent was removed under reduced pressure to give the crude product. Purification by chromatography (CH_2Cl_2/MeOH 10:1) and crystallization from ethyl acetate and hexane yielded then 5.7 g (16.6 mmol, 69 %) *(3S,4S)*-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol as a solid.

MS: m/e = 344.3 (M+1), $[\alpha]_D^{20}$ = + 37.1 (c = 1.04, CH_2Cl_2).

EXAMPLE A

Tablet Formulation (Wet Granulation)

Ingredients				mg / tablet	
1. Active compound	5	25	100	500
2. Lactose Anhydrous DTG	125	105	30	150
3. Sta-Rx 1500	6	6	6	30
4. Microcrystalline Cellulose	30	30	30	150
5. Magnesium Stearate	1	1	1	1
TOTAL	167	167	167	831

Manufacturing Procedure:

1. Mix Items 1, 2, 3 and 4 and granulate with purified water.
2. Dry the granulation at 50 °C.
3. Pass the granulation through suitable milling equipment.
4. Add Item 5 and mix for three minutes; compress on a suitable press.

Capsule Formulation

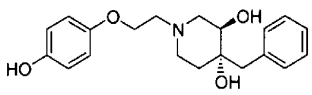
Ingredients				mg / capsule	
1. Active compound	5	25	100	500
2. Hydrous Lactose	159	123	148	- - -
3. Corn Starch	25	35	40	70
4. Talc	10	15	10	25
5. Magnesium Stearate	1	2	2	5
TOTAL	200	200	300	600

Manufacturing Procedure:

1. Mix Items 1, 2, and 3 in a suitable mixer for 30 minutes.
2. Add Items 4 and 5 and mix for 3 minutes.
3. Fill into a suitable capsule.

The claims defining the invention are as follows:

1. A compound of the formula



I,

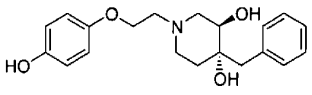
and its corresponding S,S-enantiomer and their pharmaceutically acceptable acid addition salts.

2. A compound of formula I in accordance with claim 1, which is (4R,3R) and (4S,3S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol.

3. A compound of formula I in accordance with claim 1, which is (3R,4R)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol.

4. A compound of formula I in accordance with claim 1, which is (3S,4S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol.

5. A compound of formula I



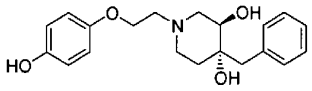
I,

and its corresponding S,S-enantiomer and their pharmaceutically acceptable acid addition salts, substantially as hereinbefore described with reference to any one of Examples 15 to 17.

6. A medicament containing one or more compounds according to any one of claims 1 to 5, which are (4R,3R) and (4S,3S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol,
(3R,4R)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol and
(3S,4S)-4-benzyl-1-[2-(4-hydroxy-phenoxy)-ethyl]-piperidine-3,4-diol
and pharmaceutically inert excipients.

7. A medicament in accordance with claim 6 for the treatment of diseases which include acute forms of neurodegeneration caused by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, and, diseases such as schizophrenia, anxiety, depression and chronic/acute pain.

8. A medicament containing one or more compounds selected from the compound of formula I



I,

and its corresponding S,S-enantiomer and their pharmaceutically acceptable acid addition salts together with one or more pharmaceutically acceptable excipients, substantially as hereinbefore described with reference to Example A.

9. The use of a compound as claimed in any one of claims 1 to 5 for the manufacture of a medicament for the treatment of diseases which include acute forms of neurodegeneration caused by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, and, diseases such as schizophrenia, anxiety, depression and chronic/acute pain.

10. A method of treating or preventing diseases which include acute forms of neurodegeneration caused by stroke or brain trauma; chronic forms of neurodegeneration such as Alzheimer's disease, Parkinson's disease, Huntington's disease or ALS (amyotrophic lateral sclerosis); neurodegeneration associated with bacterial or viral infections, and, diseases such as schizophrenia, anxiety, depression and chronic/acute pain, comprising administering a compound as claimed in any one of claims 1 to 5 or a medicament as claimed in any one of claims 6 to 8 to a patient in need thereof.

Dated 8 August, 2006
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