

**APPLICATION OF RILUZOLE- AND BORNEOL-CONTAINING COMPOSITION IN
PREPARATION OF MEDICATION FOR TREATING CEREBROVASCULAR
DISEASES**

5 CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority of Chinese Patent Application No. 202110141522.3, filed with the China National Intellectual Property Administration on February 02, 2021, and titled with “APPLICATION OF RILUZOLE- AND BORNEOL-CONTAINING COMPOSITION IN PREPARATION OF MEDICATION FOR TREATING CEREBROVASCULAR DISEASES”,
10 which is hereby incorporated by reference in its entirety.

FIELD

[0002] The present invention belongs to the field of pharmacy, and relates to use of a composition of 2-amino-6-trifluoromethoxybenzothiazole and borneol or (+)-2-borneol in the
15 manufacture of a medicament for treating cerebrovascular diseases, in particular ischemic cerebrovascular diseases.

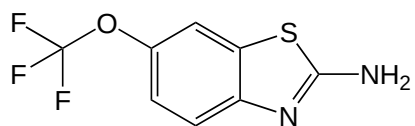
BACKGROUND

[0003] Cerebrovascular disease (CVD) refers to brain lesions caused by various
20 cerebrovascular diseases, and can be divided into acute cerebrovascular disease (stroke) and chronic cerebrovascular disease according to its pathogenesis process. Acute cerebrovascular diseases include transient ischemic attack, cerebral thrombosis, cerebral embolism, hypertensive encephalopathy, cerebral hemorrhage, subarachnoid hemorrhage, etc.; chronic cerebrovascular diseases include cerebral arteriosclerosis, cerebrovascular dementia, cerebral arterial steal
25 syndrome, Parkinson’s disease, etc. Ischemic stroke is a general term for brain tissue necrosis caused by insufficient cerebral blood supply due to stenosis or occlusion of cerebral blood supply arteries (carotid artery and vertebral artery). Cerebral ischemia includes four types, transient ischemic attack (TIA), reversible neurological deficit (RIND), stroke in progressive (SIE) and

complete stroke (CS). There is no cerebral infarction present in TIA, but there are cerebral infarction of different degrees present in RIND, SIE and CS.

[0004] 2-Amino-6-trifluoromethoxybenzothiazole (riluzole) is a benzothiazole compound, which was originally researched and developed in the 1950s as a central muscle relaxant drug. In 1995, riluzole was approved by the US FDA for treating amyotrophic lateral sclerosis (ALS). Riluzole inhibits the release of glutamate from the cultured neurons, brain slices, and *in vivo* cerebral cortical neurons, which may be attributed in part to inactivation of voltage-dependent sodium channels in glutamatergic nerve terminals, and activation of pertussis toxin (PTX)-sensitive G protein-dependent signal transduction processes. Riluzole also blocks certain postsynaptic effects of glutamate by noncompetitively blocking N-methyl-D-aspartate (NMDA) receptors (IC_{50} 18 μ M) and kainic acid receptors (IC_{50} 167 μ M). In vivo, riluzole has neuroprotective, anticonvulsant and sedative effects. In a model of transient global cerebral ischemia in rodent, riluzole completely inhibits the ischemia-induced surge in release of glutamate. In vitro, riluzole protects the cultured neurons against hypoxic injury, injury caused by the toxic effects of glutamate uptake inhibitors, and injury caused by the toxic factors in the cerebrospinal fluid of patients with amyotrophic lateral sclerosis (Neurology, 1996, 47 (6 Suppl 4), S233S–41). Afterwards, it is found through preclinical animal and clinical human trials that riluzole has certain therapeutic effects on spinal cord neuroprotection, neuralgia, epilepsy, anxiety and depression (Chinese Pharmaceutical Journal, 2015, 50 (14): 1165-1168; Chemical and Biological Engineering, 2017, 34(2): 6-9). In addition, in a systematic review and meta-analysis of riluzole for treating neurodegenerative motor diseases, including PD, atypical Parkinson's disease, Huntington disease (HD), hereditary ataxia, etc., it is indicated that the effect of riluzole on symptoms in patients with hereditary ataxia seems promising, but further clinical validation studies are still needed (Drug Delivery, 2017, 25(1), 43–48). In addition, in the rat middle cerebral artery occlusion (MCAO) model, a single intravenous injection of riluzole given at 4 mg/kg and 8 mg/kg at 30 min after ischemia can significantly reduce the neurological deficit score and cerebral infarction area (CNS Drug Reviews, 1997, 3(1), 83–101).

[0005] Riluzole has a chemical structural formula as follows:

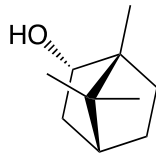


Riluzole

(molecular formula $C_8H_5F_3N_2OS$; molecular weight 234.20)

[0006] Natural borneol is the crystal extracted and processed from the fresh branches and leaves of *Cinnamomum camphora*, and has a main component of (+)-2-borneol (the 2015 edition of the Chinese Pharmacopoeia stipulates that the content of (+)-2-borneol in natural borneol should not be less than 96.0%). L-borneolum is the crystal extracted and processed from the fresh leaves of *Blumea balsamifera*, and has a main component of (-)-borneol (the 2015 edition of the Chinese Pharmacopoeia stipulates that the content of (-)-borneol in natural borneol should not be less than 85.0%). The synthetic borneol is chemically synthesized, and has main components of (+)-2-borneol and (-)-borneol. (+)-2-Borneol exhibits multiple biological activities, such as anti-inflammation, anti-oxidation, and enhancement of function of γ -aminobutyric acid (GABA) receptor (Euro J Pharmacol, 2017 811, 1–11). In addition, under physiological conditions, (+)-2-borneol can also provide delivery of central nervous system drug by temporarily reversibly increasing the permeability of the blood-brain barrier (BBB); under pathological conditions, (+)-2-borneol can maintain the integrity of the BBB and protect brain tissue (Drug Deliv 2017, 24:1037 – 1044; Drug Deliv 2018, 25:1617–1633; Biomed Pharmacother 2018, 102:874–883). In *Xenopus laevis* oocytes, (+)-2-borneol can enhance the function of recombinant human GABA_AR ($\alpha_1\beta_2\gamma_{2L}$) induced by low concentration of GABA by more than 10 times, which has an EC_{50} of 248 μ M (Biochemical Pharmacology, 2005, 69(7), 1101–1111). Natural borneol has a protective effect on glutamate-induced neuronal injury (Journal of Nanjing Medical University (Natural Science Edition) 2013, 33 (5), 630–635). In addition, (+)-2-borneol has been used as a raw material drug in the Class 1 new drug Edaravone (+)-2-borneol injection for treating ischemic stroke (CDE acceptance number CXHS1800031).

[0007] (+)-2-Borneol has a chemical structural formula as follows:



(+)-2-Borneol

(molecular formula $C_{10}H_{18}O$; molecular weight 154.25)

5 [0008] Therefore, it is of important practical significance to provide use of a composition comprising riluzole and borneol in cerebrovascular diseases.

SUMMARY

10 [0009] In view of this, the present invention provides use of a composition comprising riluzole and borneol in the manufacture of a medicament for treating a cerebrovascular disease. The composition comprises 2-amino-6-trifluoromethoxybenzothiazole or a pharmaceutically acceptable salt thereof and borneol or (+)-2-borneol. Further, the composition comprises 2-amino-6-trifluoromethoxybenzothiazole or a pharmaceutically acceptable salt thereof and (+)-2-borneol.

15 [0010] In order to achieve the above purpose of the present invention, the present invention provides the following technical solutions:

[0011] in the first aspect, the present invention provides a composition comprising the following components:

[0012] component (I), 2-amino-6-trifluoromethoxybenzothiazole, a derivative, a pharmaceutically acceptable salt or a prodrug molecule thereof; and

20 [0013] component (II), (+)-2-borneol, borneol, or a drug with an active ingredient of (+)-2-borneol.

[0014] In some specific embodiments of the present invention, the component (I) and the component (II) are in a weight ratio of 30:1-1.5:1 or 27:1-1:27.

25 [0015] In some specific embodiments of the present invention, the component (I) and the component (II) are in a weight ratio of 15:1-1.5:1.

[0016] In some specific embodiments of the present invention, the component (I) and the component (II) are in a weight ratio of 15:1-7.5:1.

[0017] In some specific embodiments of the present invention, the component (I) and the component (II) are in a weight ratio of 1:1, 1:3, 3:1, 9:1, 27:1, 1:9, 1:27, 20:1, 5:1, 15:1 and/or 8:1.

[0018] In some specific embodiments of the present invention, the borneol is selected from the group consisting of synthetic borneol, (-)-borneol, natural borneol and a combination thereof.

[0019] In the second aspect, the present invention further provides a drug comprising the composition and a pharmaceutically acceptable adjuvant.

[0020] In the third aspect, the present invention further provides use of the composition or the drug in the manufacture of a medicament for preventing and/or treating cerebrovascular diseases.

[0021] In some specific embodiments of the present invention, the cerebrovascular disease is selected from ischemic cerebrovascular disease.

[0022] In some specific embodiments of the present invention, the ischemic cerebrovascular disease is selected from ischemic stroke.

[0023] The borneol described in the above composition is selected from the group consisting of natural borneol, (-)-borneol and synthetic borneol.

[0024] The drug composition of the present invention can be used in the manufacture of a medicament for treating a cerebrovascular disease. Among them, the cerebrovascular disease is preferably ischemic cerebrovascular disease, more preferably ischemic stroke.

[0025] The present invention has the following beneficial effects:

[0026] The present invention combines 2-amino-6-trifluoromethoxybenzothiazole and (+)-2-borneol. The results of non-clinical cell tests and animal efficacy tests show that 2-amino-6-trifluoromethoxybenzothiazole and (+)-2-borneol have a synergistic effect on cerebrovascular disease.

BRIEF DESCRIPTION OF DRAWINGS

[0027] FIG. 1 shows the effects of riluzole and (+)-2-borneol on NMDA-induced neuronal injury; wherein, A shows the effect of riluzole on NMDA-induced neuron injury; B shows the effect of (+)-2-borneol on NMDA-induced neuron injury;

[0028] FIG. 2 shows the inhibitory rate of NMDA-induced neuronal injury by riluzole and (+)-2-borneol;

[0029] FIG. 3 shows the effect of riluzole, (+)-2-borneol and the composition of the two on the excitatory injury of NMDA-induced primary neurons;

[0030] FIG. 4 shows the effect of riluzole, (+)-2-borneol and the composition (20:1) on NMDA-induced nerve excitability injury; wherein A shows the effect of riluzole, (+)-2-borneol and the composition (20:1) on NMDA-induced nerve excitability injury; B shows the effect of (+)-2-borneol on NMDA-induced nerve excitability injury; C shows the effect of the composition of riluzole and (+)-2-borneol (20:1) on NMDA-induced nerve excitability injury;

[0031] FIG. 5 shows the dose-effect curve (A), median-effect plot (B) and Fa-CI plot (C) of the composition of riluzole and (+)-2-borneol (20:1) calculated by CompuSyn software;

[0032] FIG. 6 shows the effects of riluzole, (+)-2-borneol and the composition (5:1) on NMDA-induced nerve excitability injury; wherein, A shows the effect of riluzole on NMDA-induced nerve excitability injury; B shows the effect of (+)-2-borneol on NMDA-induced nerve excitability injury; C shows the effect of the composition of riluzole and (+)-2-borneol (5:1) on NMDA-induced nerve excitability injury;

[0033] FIG. 7 shows the effects of riluzole, (+)-2-borneol and the combination (1:1) on NMDA-induced nerve excitability injury; wherein, A shows the effect of riluzole on NMDA-induced nerve excitability injury; B shows the effect of (+)-2-borneol on NMDA-induced nerve excitability injury; C shows the effect of the composition of riluzole and (+)-2-borneol (1:1) on NMDA-induced nerve excitability injury;

[0034] FIG. 8 shows the effect of the composition of riluzole and (+)-2-borneol on neurological deficit symptom in MCAO rats;

[0035] FIG. 9 shows the effect of the composition of riluzole and (+)-2-borneol on the cerebral infarction area;

[0036] FIG. 10 shows the dose-effect curve (A), median-effect plot (B) and Fa-CI plot (C) of the compositions of riluzole and (+)-2-borneol (with a mass ratio of 8:1 and 15:1) reducing the cerebral infarction area of MCAO rats calculated by CompuSyn software;

[0037] FIG. 11 shows the effect of the compositions of riluzole with (+)-2-borneol, (-)-borneol or synthetic borneol on neurological deficit score and cerebral infarction area in MCAO rats; wherein, A shows the effect of the compositions of riluzole with (+)-2-borneol, (-)-borneol or synthetic borneol on neurological deficit score in MCAO rats; B shows the effect of the compositions of riluzole with (+)-2-borneol, (-)-borneol or synthetic borneol on the cerebral infarction area in MCAO rats.

DETAILED DESCRIPTION

[0038] The present invention discloses use of a composition comprising riluzole and borneol in the manufacture of a medicament for treating a cerebrovascular disease. Those skilled in the art can refer to the content of this article and appropriately improve the process parameters to realize the present invention. In particular, it should be noted that all similar replacements and modifications are apparent to those skilled in the art, and they are all considered to be included in the present invention. The method and use of the present invention have been described through preferred embodiments, and those skilled in the art can apparently make modifications or appropriate changes and combinations of the method and use described herein without departing from the content, spirit and scope of the present invention to realize and apply the technology of the present invention.

[0039] In the use of a composition comprising riluzole and borneol in the manufacture of a medicament for treating a cerebrovascular disease provided by the present invention, the raw materials and reagents used were all commercially available.

[0040] The present invention will be further illustrated below in conjunction with examples:

Example 1 Effects of riluzole and (+)-2-borneol on NMDA-induced excitatory injury of primary cortical neurons

[0041] 1 Materials and methods

[0042] 1.1 Animals

[0043] SD pregnant rats, Shanghai Slac Experimental Animal Co., Ltd. (production license number: SCXK (Shanghai) 2017-0005)

5 **[0044]** 1.2 Reagents and consumables

Name	Catalogue number/batch number	Manufacturer
Neurobasal	21103-049	Gibco
B27	17504-044	Gibco
GlutaMax	2110349	Gibco
CellTiter-Glo	G7571	Promega
Poly-D-lysine (PDL)	P6407	Sigma
DMEM	11995-040	Gibco
Sugar-free DMEM	1763966	Gibco
Penicillin Streptomycin (P/S)	15140-122	Gibco
Fetal Bovine Serum (FBS)	10099-141	Gibco
Cell Culture Plate	Corning 3610/96 well cell culture plate	Corning
Riluzole	R129533-5g (Lot1502089)	Aladdin
(+)-2-Borneol	KC20171205-1-2	Jiangsu Simovay Pharmaceutical Co., Ltd.
CellCounting-Lite 2.0 Luminescent Cell Viability Assay	LOT 7E322D9	Nanjing vazyme Medical Technology Co., Ltd.

[0045] 1.3 Preparation of primary cortical neurons

[0046] Pregnant SD rats at 18 days of pregnancy were sacrificed by cervical dislocation. The

uterus of rats was dissected and the brain of E18 fetal rats was taken out. The cerebral cortex tissue of the fetal rats was separated into ice-cold DMEM. The meninges and blood vessels on the cortical tissue were removed under a dissecting microscope. The cortical tissue was transferred into ice-cold DMEM, cut into pieces (about 1 mm³), and digested with trypsin at 37 °C for 10 min.

5 The digestion was stopped with FBS. The obtained cells were blown gently with a Pasteur pipette and passed through a 200-mesh sieve. The filtered cell suspension was transferred to a 15 mL centrifuge tube, and centrifuged at 1000 rpm for 5 min. The supernatant was discarded. Then the cell mass at the bottom of the centrifuge tube was blown gently with 37 °C-prewarmed complete medium (Neurobasal+ B27 + GlutaMax + 1% P/S). The cells were counted using a
10 hemocytometer, diluted to 5×10⁵ cells/mL with complete medium, and seeded in a 96-well plate coated with PDL (100 µL/well). Half of the cell culture medium was replaced with complete medium the next day. The cells were cultured in vitro until the 11th day when the neurons differentiated and matured, and then used for the oxygen-glucose deprivation test.

[0047] 1.4 NMDA-induced excitatory injury test on primary cortical neurons

15 **[0048]** The culture medium of the primary neurons matured in vitro was replaced with different concentrations (100, 33.3, 11.1, 3.7, 1.23 and 0.41 µM) of riluzole (R) or (+)-2-borneol in Locke's buffer (NaCl 154 mM, KCl 5.6 mM, NaHCO₃ 3.6 mM, CaCl₂ 2.3 mM, D-Glucose 5.6 mM, HEPES 5 mM, pH7.4). After incubation at 37 °C for 10 min, an excitatory inducing agent (NMDA at a final concentration of 100 µM and glycine at a final concentration of 10 µM) was
20 added to induce cells for 30 min. After the inducing buffer was discarded, the cells were washed once with a Locke's buffer containing 1 mM MgCl₂, and recovered to be incubated for 4 h by replacing with a complete medium (100 µL/well).

[0049] 1.5 Determination of viability of neuron cells

[0050] The viability of the primary neuron cells was determined by Luminescent Cell Viability
25 Assay kit. According to the instruction, reagents were added at 100 µL/well, and shaking was performed for 10 min. The chemiluminescence value (LUM) was read on the SpectraMax i3X (Molecule Device) multifunctional plate reader, and the relative activity of neurons was calculated.

[0051] Calculation formula: relative neuron activity V (%)=(LUM-LUM_{background})/(LUM_{normal})

control group-LUM_{background group})×100%. LUM_{background} was the background reading of the Luminescent Cell Viability Assay reagent added to the cell-free complete medium well.

[0052] 1.6 Neuroprotective effects of compounds

[0053] The neuroprotective effect of the compounds on excitatory injury was indicated by using the compounds to inhibit excitatory injury of neurons. Relative inhibition rate=100%×(V_{compound}-V_{NMDA model})/(V_{normal control group}-V_{NMDA model}), where V represents the relative activity of neurons.

[0054] Fitting of EC₅₀ of compounds: Log[compound concentration] was used as the abscissa and the relative inhibition rate was used as the ordinate. Log(inhibitor) vs. response -- variable slope (four parameters) curve was fitted by Prism8 (GraphPad) to obtain the IC₅₀ of the compounds.

[0055] 1.7 Statistics

[0056] The experimental data are expressed as mean ± standard deviation (Mean ± SD) (n=3). After performing one-way analysis of variance (ANOVA) with Prism 8 (GraphPad), the differences between two groups were analyzed with Uncorrected Fisher's LSD. P<0.05 means significant difference. ###p<0.001, compared with the control group; *p<0.05, **p<0.01, ***p<0.001, compared with the NMDA model group.

[0057] 2 Experimental results

[0058] 2.1 Effects of riluzole and (+)-2-borneol on NMDA-induced neuron injury

[0059] Within the concentration range of 0.41-100 μM, riluzole concentration-dependently increased the viability of neurons induced by NMDA, and it could significantly increase the viability of neurons at the concentrations of 33.3 and 100 μM (FIG. 1A). Within the concentration range of 0.41-3.7 μM, (+)-2-borneol concentration-dependently increased the viability of neurons with excitatory injury, but as the concentration increased (10-100 μM), the viability of neurons tended to decrease (FIG. 1B).

[0060] According to the compound concentration-inhibition rate curve, the EC₅₀ of riluzole and (+)-2-borneol for neuroprotection was about 40 μM (E_{max}-60%) and 2 μM (E_{max}-15%), respectively (FIG. 2).

Example 2 Effects of compositions of riluzole and (+)-2-borneol on NMDA-induced excitatory injury of primary cortical neurons

[0061] 1 Materials and methods

5 **[0062]** 1.1 Animals were the same as in Example 1.

[0063] 1.2 Reagents and consumables were the same as in Example 1.

[0064] 1.3 Preparation of primary cortical neurons was conducted by the same method as in Example 1.

[0065] 1.4 Experiment of NMDA-induced excitatory injury of primary cortical neurons

10 **[0066]** The culture medium of the primary neurons matured in vitro was replaced with different concentrations of riluzole (R), (+)-2-borneol (B) or compositions of riluzole and (+)-2-borneol (RB) in Locke's buffer (NaCl 154 mM, KCl 5.6 mM , NaHCO₃ 3.6 mM, CaCl₂ 2.3 mM, D-Glucose 5.6 mM, HEPES 5 mM, pH7.4)(See Table 1). After incubation at 37 °C for 10 min, an
15 excitatory inducing agent (NMDA at a final concentration of 100 µM and glycine at a final concentration of 10 µM) was added to induce cells for 30 min. After the inducing buffer was discarded, the cells were washed once with a Locke's buffer containing 1 mM MgCl₂, and recovered to be incubated for 4 h by replacing with a complete medium (100 µL/well).

Table 1 Orthogonal design of compositions of riluzole and (+)-2-borneol

DMSO	R1	R2	R3	R4	R5	R6
B1	R1 B1	R2B1	R3B1	R4B1	R5B1	R6B1
B2	R1 B2	R2B2	R3B2	R4B2	R5B2	R6B2
B3	R1 B3	R2B3	R3B3	R4B3	R5B3	R6B3
B4	R1 B4	R2B4	R3B4	R4B4	R5B4	R6B4
B5	R1 B5	R2B5	R3B5	R4B5	R5B5	R6B5
B6	R1B6	R2B6	R3B6	R4B6	R5B6	R6B6

[0067] Note: R represents riluzole, B represents (+)-2-borneol, R_XB_Y represents compositions of riluzole and (+)-2-borneol, X/Y of 1-6 represents the concentrations of the respective compounds, respectively 100, 33.3, 11.1, 3.7 , 1.23 and 0.41 µM. Each group of drugs had 5

replicate wells (n=5). All compounds were first dissolved in DMSO, and the final concentration of DMSO in the cell culture medium was 0.2%.

[0068] 1.5 Determination of viability of neuron cells was performed by the same method as in Example 1.

5 **[0069]** 1.6 Statistics was performed by the same method as in Example 1.

[0070] The experimental data are expressed as mean $\pm$ standard deviation (Mean $\pm$ SD) (n=3). After performing one-way ANOVA with Prism 8 (GraphPad), the differences between two groups were analyzed with Uncorrected Fisher's LSD. P<0.05 means significant difference. ###p<0.001, compared with Control (control group); *p<0.05, **p<0.01, compared with NMDA model group.

10 **[0071]** 2 Experimental results

[0072] 2.1 Effects of compositions of riluzole and (+)-2-borneol on excitatory injury of primary neurons

[0073] As shown in FIG. 3, within the concentration range of 0.41-100 μ M, riluzole alone at the concentration of R2 (33.3 μ M) can significantly increase the viability of neurons with NMDA-induced excitatory injury. (+)-2-Borneol at the concentration of R4 (3.7 μ M) can significantly improve the viability of neurons with NMDA-induced excitatory injury. The compositions of riluzole and (+)-2-borneol, namely R1B1 (1:1), R2B1 (1:3), R2B2 (1:1), R2B3 (3:1), R2B4 (9:1), R2B5 (27:1), R3B1(1:9), R3B2(1:3), R3B3(1:1), R3B4(3:1), R3B5(9:1), R3B6(1:27), R4B1(1:27), R4B2 (1:9), R4B3 (1:3), R4B4 (1:1), R4B5 (3:1) and R4B6 (9:1) can significantly improve the viability of neurons induced by NMDA. This indicates that the combination of riluzole and (+)-2-borneol at a ratio of 27:1 to 1:27 may produce a synergistic effect on neuroprotection.

Example 3 Study of synergistic effect of compositions of riluzole and (+)-2-borneol (20:1) on protecting primary neurons from excitatory injury

[0074] 1 Materials and methods

[0075] 1.1 Animals were the same as in Example 1.

[0076] 1.2 Reagents and consumables were the same as in Example 1.

[0077] 1.3 Preparation of primary cortical neurons was performed by the same method as in Example 1.

[0078] 1.4 Experiment of NMDA-induced excitatory injury of primary cortical neurons

5 **[0079]** The culture medium of the primary neurons matured in vitro was replaced with different concentrations of riluzole (R), (+)-2-borneol (B) or compositions of riluzole and (+)-2-borneol (20: 1) in Locke's buffer (See Table 2). After incubation at 37 °C for 10 min, an excitatory inducing agent (NMDA at a final concentration of 100 µM and glycine at a final concentration of 10 µM) was added to induce cells for 30 min. After the inducing buffer was discarded, the cells
10 were washed once with a Locke's buffer containing 1 mM MgCl₂, and recovered to be incubated for 4 h by replacing with a complete medium (100 µL/well).

Table 2 Concentration design of compositions of riluzole and (+)-2-borneol

Composition	Riluzole (µM)	(+)-2-Borneol (µM)
Riluzole	10	/
	20	/
	40	/
	80	/
	160	/
(+) -2-Borneol	/	0.5
	/	1
	/	2
	/	4
	/	8
Riluzole: (+) -2-borneol=20:1	10	0.5
	20	1

Composition	Riluzole (μM)	(+)-2-Borneol (μM)
	40	2
	80	4
	160	8

[0080] 1.5 Determination of viability of neuron cells was performed by the same method as in Example 1.

[0081] 1.6 Neuroprotective effects of compounds were determined by the same method as in Example 1.

5 **[0082]** 1.7 Analysis of synergistic effect of compositions

[0083] The synergistic effect on neuroprotection of the compositions of riluzole and (+)-2-borneol at the fixed ratio was analyzed using CompuSyn software (ComboSyn, Inc).

[0084] 1.8 Statistics

[0085] The experimental data are expressed as mean $\pm$ standard deviation (Mean $\pm$ SD) (n=3-6).
 10 After performing one-way ANOVA with Prism 8 (GraphPad), the differences between two groups were analyzed with Uncorrected Fisher's LSD. $P < 0.05$ means significant difference. ### $p < 0.001$ compared with control group; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, compared with NMDA model group.

[0086] 2 Experimental results

15 **[0087]** 2.1 Effects of riluzole, (+)-2-borneol and compositions of the two (20:1) on excitatory injury of primary neurons

[0088] According to the results of Example 1, the concentrations of the compounds were designed to be $1/4 \times \text{ED}_{50}$, $1/2 \times \text{ED}_{50}$, $1 \times \text{ED}_{50}$, $2 \times \text{ED}_{50}$ and $4 \times \text{ED}_{50}$, where the concentrations of riluzole were 10, 20, 40, 80 and 160 μM , the concentrations of (+)-2-borneol
 20 were 0.5, 1, 2, 4 and 8 μM , and the molar ratio of the compositions of riluzole and (+)-2-borneol was 20:1. Riluzole, (+)-2-borneol and the compositions of the two can concentration-dependently increase the viability of neurons with injury induced by NMDA, and the effect of the compositions was better than that of riluzole or (+)-2-borneol (FIG. 3).

[0089] 2.2 Analysis of synergistic effect on neuroprotection of compositions of riluzole and (+)-2-borneol

[0090] According to the principle of the Chou-Talalay equation, the combination index (CI) of the compositions at the fixed ratio was calculated using CompuSyn software (see Table 3, FIG. 5), and the compositions of riluzole and (+)-2-borneol at the molar ratio of 20: 1 had CI<1, indicating that riluzole and (+)-2-borneol have a synergistic effect on protecting neurons from excitatory injury.

Table 3 Effect (Fa) and combination index (CI) of compositions of riluzole and (+)-2-borneol in protecting neurons from excitatory injury

Riluzole		(+)-2-Borneol		Composition of riluzole / (+)-2-borneol (20: 1)		
Concentration (μ M)	Fa	Concentration (μ M)	Fa	Concentration (μ M)	Fa	CI
160	0.847	8	0.231	160 / 8	0.932	0.784
80	0.842	4	0.22	80 / 4	0.878	0.608
40	0.523	2	0.152	40 / 2	0.78	0.492
20	0.219	1	0.022	20 / 1	0.477	0.621
10	0.118	0.5	0.014	10 / 0.5	0.288	0.542

Example 4 Study of synergistic effect of compositions of riluzole and (+)-2-borneol (5:1) on protecting primary neurons from excitatory injury

[0091] 1 Materials and methods

[0092] 1.1 Animals were the same as in Example 1.

[0093] 1.2 Reagents and consumables were the same as in Example 1.

[0094] 1.3 Preparation of primary cortical neurons was performed by the same method as in Example 1.

[0095] 1.4 Experiment of NMDA-induced excitatory injury of primary cortical neurons

[0096] The culture medium of the primary neurons matured in vitro was replaced with different concentrations of riluzole (R), (+)-2-borneol (B) or compositions of riluzole and (+)-2-borneol (5:1) in Locke's buffer (See Table 2). After incubation at 37 °C for 10 min, an excitatory inducing agent (NMDA at a final concentration of 100 µM and glycine at a final concentration of 10 µM) was added to induce cells for 30 min. After the inducing buffer was discarded, the cells were washed once with a Locke's buffer containing 1 mM MgCl₂, and recovered to be incubated for 4 h by replacing with a complete medium (100 µL/well).

Table 4 Concentration design of compositions of riluzole and (+)-2-borneol

Composition	Riluzole (µM)	Borneol (µM)
Riluzole	2.5	/
	5	/
	10	/
	20	/
	40	/
(+) -2-borneol	/	0.5
	/	1
	/	2
	/	4
	/	8
Riluzole : (+)-2-borneol =5:1	2.5	0.5
	5	1
	10	2
	20	4
	40	8

[0097] 1.5 Determination of viability of neuron cells was performed by the same method as in

Example 1.

[0098] 1.6 Neuroprotective effects of compounds were determined by the same method as in Example 1.

[0099] 1.7 Analysis of synergistic effect of compositions

5 **[00100]** The synergistic effect on neuroprotection of the compositions of riluzole and (+)-2-borneol at the fixed ratio was analyzed using CompuSyn software (ComboSyn, Inc).

[00101] 1.8 Statistics was performed by the same method as in Example 3.

[00102] 2 Experimental results

10 **[00103]** 2.1 Effects of riluzole, (+)-2-borneol and compositions of the two (5:1) on excitatory injury of primary neurons

[00104] The concentrations of riluzole were 2.5, 5, 10, 20 and 40 μM , the concentrations of (+)-2-borneol were 0.5, 1, 2, 4 and 8 μM , and the molar ratio of the compositions of riluzole and (+)-2-borneol was 5:1. Riluzole, (+)-2-borneol and the compositions of the two can concentration-dependently increase the viability of neurons with injury induced by NMDA, and
15 the compositions (5:1) had a better effect than riluzole or (+)-2-borneol (FIG. 6).

[00105] 2.2 Analysis of synergistic effect on neuroprotection of compositions of riluzole and (+)-2-borneol

[00106] According to the principle of the Chou-Talalay equation, the combination index (CI) of the compositions at the fixed ratio was calculated using CompuSyn software (see Table 5), and
20 the compositions of riluzole and (+)-2-borneol at the molar ratio of 5:1 had $\text{CI} < 1$, indicating that riluzole and (+)-2-borneol have a synergistic effect on protecting neurons from excitatory injury.

Table 5 Effect (Fa) and combination index (CI) of compositions of riluzole and (+)-2-borneol in protecting neurons from excitatory injury

Riluzole		(+) -2-Borneol		Composition of riluzole/ (+)-2-borneol (5: 1)		
Concentration (μM)	Fa	Concentration (μM)	Fa	Concentration (μM)	Fa	CI

40	0.469	8	0.205	40 / 8	0.592	0.673
20	0.297	4	0.209	20/ 4	0.408	0.729
10	0.118	2	0.086	10 / 2	0.358	0.456
5	0.081	1	0.069	5 / 1	0.182	0.617
2.5	0.048	0.5	0.042	2.5/ 0.5	0.100	0.673

Example 5 Study of synergistic effect of compositions of riluzole and (+)-2-borneol (1:1) on protecting primary neurons from excitatory injury

[00107] 1 Materials and methods

5 **[00108]** 1.1 Animals were the same as in Example 1.

[00109] 1.2 Reagents and consumables were the same as in Example 1.

[00110] 1.3 Preparation of primary cortical neurons was performed by the same method as in Example 1.

[00111] 1.4 Experiment of NMDA-induced excitatory injury of primary cortical neurons

10 **[00112]** The culture medium of the primary neurons matured in vitro was replaced with different concentrations of riluzole (R), (+)-2-borneol (B) or compositions of riluzole and (+)-2-borneol (1:1) in Locke's buffer (See Table 2). After incubation at 37 °C for 10 min, an excitatory inducing agent (NMDA at a final concentration of 100 µM and glycine at a final concentration of 10 µM) was added to induce cells for 30 min. After the inducing buffer was discarded, the cells were
15 washed once with a Locke's buffer containing 1 mM MgCl₂, and recovered to be incubated for 4 h by replacing with a complete medium (100 µL/well).

Table 6 Concentration design of compositions of riluzole and (+)-2-borneol

Composition	Riluzole (µM)	(+)-2-Borneol (µM)
Riluzole	0.5	/
	1	/
	2	/

Composition	Riluzole (μM)	(+)-2-Borneol (μM)
	4	/
	8	/
(+) -2-Borneol	/	0.5
	/	1
	/	2
	/	4
	/	8
Riluzole: (+)-2-borneol =1:1	0.5	0.5
	1	1
	2	2
	4	4
	8	8

[00113] 1.5 Determination of viability of neuron cells was performed by the same method as in Example 1.

[00114] 1.6 Neuroprotective effects of compounds were determined by the same method as in Example 1.

5 **[00115]** 1.7 Analysis of synergistic effect of compositions

[00116] The synergistic effect on neuroprotection of the compositions of riluzole and (+)-2-borneol at the fixed ratio was analyzed using CompuSyn software (ComboSyn, Inc).

[00117] 1.8 Statistics was performed by the same method as in Example 3.

[00118] 2 Experimental results

10 **[00119]** 2.1 Effects of riluzole, (+)-2-borneol and compositions of the two (1:1) on excitatory injury of primary neurons

[00120] The concentrations of riluzole were 0.5, 1, 2, 4 and 8 μM , the concentrations of (+)-2-borneol were 0.5, 1, 2, 4 and 8 μM , and the molar ratio of the compositions of riluzole and (+)-2-borneol was 1:1. The protective effect of riluzole in this concentration range has a certain concentration-dependence. (+)-2-Borneol and the compositions (1:1) can concentration-dependently increase the viability of neurons with injury induced by NMDA. The compositions (1:1) had a better effect than riluzole or (+)-2-borneol (FIG. 7).

[00121] 2.2 Analysis of synergistic effect on neuroprotection of compositions of riluzole and (+)-2-borneol

[00122] According to the principle of the Chou-Talalay equation, the combination index (CI) of the compositions at the fixed ratio was calculated using CompuSyn software (see Table 7), and the compositions of riluzole and (+)-2-borneol at the molar ratio of 1:1 had $\text{CI} < 1$, indicating that riluzole and (+)-2-borneol have a synergistic effect on protecting neurons from excitatory injury.

Table 7 Effect (Fa) and combination index (CI) of compositions of riluzole and (+)-2-borneol in protecting neurons from excitatory injury

Riluzole		(+)-2-Borneol		Composition of riluzole/ (+)-2-borneol (1: 1)		
Concentration (μM)	Fa	Concentration (μM)	Fa	Concentration (μM)	Fa	CI
8	0.116	8	0.202	8/ 8	0.202	0.765
4	0.055	4	0.205	4/ 4	0.205	0.580
2	0.042	2	0.128	2/ 2	0.128	0.610
1	0.029	1	0.077	1 / 1	0.077	0.704
0.5	0.017	0.5	0.042	0.5/ 0.5	0.042	0.765

Example 6 Study on the protective effect of compositions of riluzole and (+)-2-borneol on focal cerebral ischemia-reperfusion injury

[00123] 1 Materials and methods

[00124] 1.1 Experimental animals

[00125] Sprague-Dawley (SD) rats, male, SPF-grade, weighing 250-280 g.

[00126] 1.2 Test drugs

[00127] Riluzole and (+)-2-borneol were the same as in Example 1.

[00128] 1.3 Experimental method

5 **[00129]** 1.3.1 Establishment of focal cerebral ischemia-reperfusion model

[00130] The rat focal cerebral ischemia-reperfusion model was established by internal carotid artery suture method. The limbs (hind limbs above the knee joint and forelimbs above the wrist joint) and head of an anesthetized rat were tightened with rubber bands. The animal was fixed on an operating table in supine position, and was shaved with an animal shaver from the head to the chest, and the skin was disinfected with alcohol. The neck of the rat was cut at the midline, and the subcutaneous tissue was bluntly separated. The thin layer of fascia on the surface of the anterior triangle of the neck was separated, the lower side-lower edge of the clavicular hyoid muscle was pulled up, and the longitudinally pulsating artery parallel to this muscle can be seen. The arterial shell was opened, and the bifurcation of the right carotid artery was exposed. The right common carotid artery, external carotid artery and internal carotid artery were separated. The vagus nerve was gently stripped, and the external carotid artery was ligated and cut. The proximal end of the common carotid artery was clamped. An incision was made at the distal end from the ligature of the external carotid artery, and was inserted with a suture line, which was passed through the bifurcation of the common carotid artery into the internal carotid artery, and then was inserted slowly until reaching slight resistance (approximately 20 mm from the bifurcation), so as to block all blood supply to the middle cerebral artery. The suture line was slightly fixed below the incision of the external carotid artery with silk thread. The silk thread clamping the proximal end of the common carotid artery was loosened. A gauze soaked in sterile saline was covered on the wound, and the rat was placed on a heat preservation pad to keep warm. 2.0 h after cerebral ischemia on the right side, the suture line was pulled out gently to restore the blood supply for reperfusion. The external carotid artery was ligated with silk thread fixing the suture line. The skin was stitched, and disinfected. The rats were placed in clean feed, and their general condition and respiration were observed until they woke up from anesthesia. The rats were provided with food and water, and commonly reared.

[00131] 1.3.2 Grouping and administration of animals

[00132] The experimental animals were divided into riluzole groups (6 mg/kg and 12 mg/kg, i.v.), (+)-2-borneol groups (0.4 mg/kg and 0.8 mg/kg, i.v.), the composition of riluzole and (+)-2-borneol group (6.4 mg/kg and 12.8 mg/kg, i.v., riluzole: (+)-2-borneol = 15:1) and model group, a total of 9 groups. After the cerebral ischemia model was established, the animals were assigned to each group in a single-blind manner with equal probability. After reperfusion, the animals were immediately administered intravenously with the drugs once. The animals in the model group were administered with an equal volume of normal saline. Neurological deficit symptoms were evaluated 24 hours after cerebral ischemia, the animals were sacrificed, and their brains were taken out, stained, and photographed for determining the area of cerebral infarction.

[00133] 1.3.3 Scoring of neurological deficit symptoms and determination of cerebral infarction area

[00134] Neurological deficit symptoms were evaluated using the modified Bederson 5-point scale. The neurological deficit symptoms of rats after cerebral ischemia were evaluated by a single-blind method. That is, the test designer marked the animals into groups, and the tester who scored the neurological deficit symptoms did not know the grouping of the animals. After scoring, the scoring results of various markers were submitted to the designer, who unblinded and obtained the scoring of each animal in each experimental group.

Table 8 Neurological deficit symptom scoring Bederson 5-point scale

0	When the animal was suspended in the air by the tail, both its forelimbs were extended towards the floor, and there were no other behavioral defects.
1	When the animal was suspended in the air by the tail, its forelimb on the opposite (left) side of the surgery showed wrist and elbow flexion, shoulder internal rotation, elbow abduction and close to the chest wall.
2	When the animal was placed on a smooth flat surface, the resistance was reduced when pushing the shoulder on the surgery side to the opposite side.

3 When the animal walked freely, it circled or turned around the opposite side of the surgery.

4 The limbs were flaccid, with no spontaneous movement.

[00135] The degree of cerebral infarction was determined by TTC staining. After the evaluation of the symptoms of neurological deficits was completed, the animals were sacrificed with CO₂. The brain was taken out by cutting off head. The olfactory bulb, cerebellum and lower brainstem were removed. The blood on the surface of the brain was washed with normal saline, and the residual water on the surface was removed. The brain was placed at -20 °C for 20 min, then taken out, immediately cut to a coronal section vertically downward at the crossing plane of the line of sight, and sliced backward every 2 mm. The brain slices were incubated in 1% TTC staining solution (at 37 °C for 30 min). The normal brain tissue was stained into dark red, and the ischemic brain tissue was stained into pale white. After being washed with normal saline, the brain slices were quickly arranged in a row from front to back, removed off the residual water on the surface, and photographed.

[00136] Calculation of area of cerebral infarction: The photos were processed by Image J software, and the corresponding area of left brain and non-infarction area of right brain were calculated according to the formula, so that the percentage of the area of infarction was calculated.

[00137] Calculation of volume of infarction:

[00138] $V=t(A_1+A_2+A_3+.....+A_n)$,

[00139] t is the thickness of a slice, A is the area of infarction.

20 [00140] $\%I=100\% \times (V_C-V_L)/V_C$,

[00141] %I is the percentage of volume of infarction, V_C is the brain volume of the control side (left brain), and V_L is the volume of the non-infarction area of the infarction side (right brain).

[00142] 1.4 Analysis of synergistic effect of compositions

[00143] The synergistic effect on neuroprotection of the compositions of riluzole and

(+)-2-borneol at the non-fixed ratio was analyzed using CompuSyn software (ComboSyn, Inc).

[00144] 1.5 Statistics

[00145] The experimental data are expressed as mean $\pm$ standard deviation (Mean $\pm$ SD) (n=10). After performing one-way analysis of variance (ANOVA), the differences between two groups were analyzed with Fisher's LSD. $P < 0.05$ means significant difference. $*p < 0.05$, $**p < 0.01$, $***p < 0.001$, compared with the MCAO model group; ns means there is no statistical difference between the groups shown in the figure.

[00146] 2 Experimental results

[00147] 2.1 Effect of compositions of riluzole and (+)-2-borneol on neurological deficit symptoms

[00148] As shown in FIG. 8, riluzole, (+)-2-borneol and the composition of the two can all dose-dependently reduce the neurological deficit score of MCAO rats. Compared with the MCAO model group, the neurological deficit scores of MCAO rats in the riluzole 8 mg/kg group, (+)-2-borneol 1 mg/kg group, the composition (comprising riluzole and (+)-2-borneol in a mass ratio of 8:1) 4.5 mg/kg and 9 mg/kg group, and the composition (comprising riluzole and (+)-2-borneol in a mass ratio of 15:1) 6.4 mg/kg and 12.8 mg/kg group were significantly reduced. In addition, the neurological deficit scores in the composition groups tended to be reduced lower compared to the riluzole or (+)-2-borneol groups.

[00149] 2.2 Effect of compositions of riluzole and (+)-2-borneol on the area of cerebral infarction

[00150] As shown in FIG. 8, compared with the MCAO model group, the riluzole 4 and 8 mg/kg groups, the (+)-2-borneol 0.5 and 1 mg/kg groups, the composition (comprising riluzole and (+)-2-borneol in a mass ratio of 8:1) 4.5 mg/kg and 9 mg/kg group, the composition (comprising riluzole and (+)-2-borneol in a mass ratio of 15:1) 6.4 mg/kg and 12.8 mg/kg group dose-dependently, significantly reduced cerebral infarction area. In addition, compared with the riluzole or (+)-2-borneol group, the animals in the composition groups had a lower cerebral infarction area.

[00151] 2.3 Analysis of synergistic effect of compositions of riluzole and (+)-2-borneol on

reducing cerebral infarction area

[00152] According to the principle of the Chou-Talalay equation, the combination index (CI) of the compositions at non-fixed ratios was calculated using CompuSyn software (see Table 9, FIG. 10), and the compositions of riluzole and (+)-2-borneol at the molar ratio of 8:1 had CI<1, indicating that riluzole and (+)-2-borneol have a synergistic effect on reducing the area of cerebral infarction in MCAO rats.

Table 9 Effect (Fa) and combination index (CI) of compositions of riluzole and (+)-2-borneol in reducing the area of cerebral infarction in MCAO rats

Riluzole		(+)-2-Borneol		Composition of riluzole and (+)-2-borneol		
Dose (mg/kg)	Fa	Dose (mg/kg)	Fa	Dose (riluzole and (+)-2-borneol)(mg/kg)	Fa	CI
4	0.247	0.5	0.157	4 / 0.5 (8:1)	0.472	0.555
8	0.380	1	0.256	8 / 1 (8:1)	0.602	0.499
/	/	/	/	6 / 0.4 (15:1)	0.541	0.463
/	/	/	/	12 / 0.8 (15:1)	0.699	0.435

Example 7 Study on the protective effect of compositions of riluzole and (+)-2-borneol, (-)-borneol and synthetic borneol on focal cerebral ischemia-reperfusion injury

[00153] 1 Materials and methods

[00154] 1.1 Experimental animals were the same as in Example 6.

[00155] 1.2 Test drugs

[00156] Riluzole and (+)-2-borneol were the same as in Example 1.

[00157] (-)-Borneol and synthetic borneol were purchased from Shanghai Aladdin Biochemical Technology Co., Ltd.

[00158] 1.3 Experimental method

[00159] 1.3.1 Establishment of focal cerebral ischemia-reperfusion model was the same as in

Example 6.

[00160] 1.3.2 Grouping and administration of animals

[00161] Experimental animals were divided into the composition of riluzole and (+)-2-borneol group (8 mg/kg riluzole and 1 mg/kg (+)-2-borneol, i.v.), the composition of riluzole and (-)-borneol group (8 mg/kg riluzole and 1 mg/kg (-)-borneol), the composition of riluzole and synthetic borneol group (8 mg/kg riluzole and 1 mg/kg synthetic borneol) and model group, a total of 4 groups. After the cerebral ischemia model was established, the animals were assigned to each group in a single-blind manner with equal probability. After reperfusion, the animals were immediately administered intravenously with the drugs once. The animals in the model group were administered with an equal volume of normal saline. Neurological deficit symptoms were evaluated 24 hours after cerebral ischemia, the animals were sacrificed, and their brains were taken out, stained, and photographed for determining the area of cerebral infarction.

[00162] 1.3.3 Scoring of neurological deficit symptoms and determination of cerebral infarction area were the same as in Example 6.

[00163] 1.4 Statistics

[00164] The experimental data are expressed as mean $\pm$ standard deviation (Mean $\pm$ SD) (n=10). After performing one-way analysis of variance (ANOVA), the differences between two groups were analyzed with Fisher's LSD. $P < 0.05$ means significant difference. $*p < 0.05$, $**p < 0.01$, $***p < 0.001$, compared with the MCAO model group; ns means there is no statistical difference between the groups shown in the figure.

[00165] 2 Experimental results

[00166] 2.1 Effect of compositions on neurological deficit symptoms and cerebral infarction area in MCAO rats

[00167] As shown in FIG. 11, the composition of riluzole (8 mg/kg) with (+)-2-borneol (1 mg/kg), (-)-borneol (1 mg/kg) or synthetic borneol (1 mg/kg) can all significantly reduce the neurological deficit score and cerebral infarction area in MCAO rats. Furthermore, in terms of neurological deficit score and cerebral infarction area, there were no differences among the three compositions.

[00168] The use of a composition comprising riluzole and borneol in the manufacture of a medicament for treating a cerebrovascular disease provided by the present invention has been introduced in detail above. Specific examples are used herein to illustrate the principle and embodiments of the present invention. The description of the above examples is only used to help
5 understand the method and core idea of the present invention. It should be noted that for those skilled in the art, without departing from the principles of the present invention, several improvements and modifications can be made to the present invention, and these improvements and modifications also fall within the protection scope of the claims of the present invention.

CLAIMS

1. A composition, comprising the following components:

component (I), 2-amino-6-trifluoromethoxybenzothiazole, a derivative, a pharmaceutically acceptable salt or a prodrug molecule thereof; and

component (II), (+)-2-borneol, borneol, or a drug with an active ingredient of (+)-2-borneol.

2. The composition according to claim 1, wherein the component (I) and the component (II) are in a weight ratio of 30:1-1.5:1.

3. The composition according to claim 1, wherein the component (I) and the component (II) are in a weight ratio of 15:1-1.5:1.

4. The composition according to claim 1, wherein the component (I) and the component (II) are in a weight ratio of 15:1-7.5:1.

5. The composition according to claim 1, wherein the component (I) and the component (II) are in a weight ratio of 1:1, 1:3, 3:1, 9:1, 27:1, 1:9, 1:27, 20:1, 5:1, 15:1 and/or 8:1.

6. The composition according to any one of claims 1 to 5, wherein the borneol is selected from the group consisting of synthetic borneol, (-)-borneol, natural borneol and a combination thereof.

7. A drug, comprising the composition according to any one of claims 1 to 6 and a pharmaceutically acceptable adjuvant.

8. Use of the composition according to any one of claims 1 to 6 or the drug according to claim 7 in the manufacture of a medicament for preventing and/or treating a cerebrovascular disease.

9. The use according to claim 8, wherein the cerebrovascular disease is selected from ischemic cerebrovascular disease.

10. The use according to claim 8, wherein the ischemic cerebrovascular disease is selected from ischemic stroke.